SPACE TELESCOPE: 1984

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

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SPACE TELESCOPE: 1984

TUESDAY, MAY 22, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:40 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Present: Representatives Volkmer, Brown, Lujan, Walker, and Chandler.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today the subcommittee opens hearings on the space telescope. The space telescope has been one of the largest development programs ever undertaken by NASA. It is a major step in achieving a better understanding of the universe, and will be a centerpiece for astronomy in the coming decades.

Since the program first began nearly 8 years ago, the subcommittee has supported the space telescope despite its large cost overruns, schedule slips, and management problems. The progress has been painful. We have seen other important programs underfunded and delayed and the overall budget in space science and applications seriously constrained, yet we have continued to defend the space telescope program because we believe that the benefits will be well worthwhile.

This is a particularly opportune time to hold these hearings. Because of our preoccupation with solving the developmental problems which have arisen, I fear that we have to some degree lost sight of the true science goals of the space telescope program. We must now look beyond any immediate problems and focus our attention on the postlaunch era. We will examine how the Space Telescope Observatory will interact with the Space Transportation System and what will be required for ongoing maintenance and refurbishment. The recent repair of the Solar Max satellite has demonstrated the potential value of man in space.

In viewing the space telescope as the first of a new generation of permanent space observatories, it is important to ask what the concept of permanence means. I believe that it must encompass not only longevity in space but also continuity in scientific return. What must we do to ensure that the full scientific potential of the observatory is realized throughout its lifetime?

It is also important to reexamine the relationship between the observatory and its users which is realized through the Space Tele-

scope Science Institute. It is appropriate to revisit the original concept of the Science Institute and assess our experience thus far. Have we adequately defined the Institute's scope of responsibilities? How does the science community view its relationship with the Institute? These are questions that will have a direct bearing on other future astronomical observatories such as AXAF and SIRTF.

Finally, we will want to review the remaining technical challenges which need to be overcome in the developmental program. We are fast approaching the crucial systems integration phase, and we cannot afford to discover any major technical problems at this stage.

Today we are pleased to have with us several distinguished scientists who have had a close association with the space telescope program and the Science Institute. First we will hear testimony from Dr. Lyman Spitzer of Princeton University, who is chairman of the Space Telescope Institute Council. He will be joined by Dr. George Field, who chairs the Space Telescope Institute Advisory Committee. We will thereafter hear from Dr. Robert Bless of the University of Wisconsin, who heads the Space Telescope Observatory performance assessment team.

Before proceeding to the witnesses, I would like to recognize the gentleman from California if he has any opening statement he may like to make.

Mr. BROWN. I have no statement.

Mr. VOLKMER. I will now then ask for Dr. Spitzer and Dr. Field to come to the table. Your statements will be made a part of the record at this point in the record in full, and you may either review your statements in full or summarize, however you so desire. We will hear from both of you before we go to any questions. I will now recognize Dr. Spitzer.

STATEMENT OF DR. LYMAN SPITZER, JR., PRINCETON UNIVERSITY OBSERVATORY, CHAIRMAN, SPACE TELESCOPE INSTITUTE COUNCIL

Dr. SPITZER. Thank you, Mr. Chairman.

Two years ago I had the privilege of reporting to this same committee concerning the activities of AURA's Space Telescope Institute Council and, in particular, our discussions of policies and problems relating to the Space Telescope Science Institute. Chairman Volkmer has asked me to report to you again discussing the development of the Science Institute, especially the matters addressed by our Institute Council.

Let me first review briefly the organization of our council. As you know, AURA is a consortium of 17 U.S. universities which manages the National Optical Astronomy Observatories for the NSF as well as the ST Science Institute for NASA. AURA establishes policies for these centers to optimize their effectiveness in providing telescope facilities for visiting astronomers, and interacts with funding agencies and the astronomical community to promote this objective.

Organizationally, the director of the Science Institute, Dr. Giacconi, reports to the AURA board of directors through AURA's

president, Dr. John Teem. The Space Telescope Institute Council, functioning as a subcommittee of the AURA board, exercises administrative oversight of the Science Institute, partly through frequent consultation with Dr. Giacconi and partly through close contact with the various NASA officials who are involved with the Science Institute program.

Our council has had an excellent opportunity to follow the development of the Science Institute since its inception in 1980. We have been enormously impressed by what we have seen. Dr. Giacconi, building on the initial organization set up by Arthur Code as acting director and with vital support by AURA, has assembled a really outstanding group with a number of brilliant astronomers. This Institute has developed a deep understanding of the requirements and operational possibilities of the space telescope and has already made many vital contributions to the space telescope program. This deep respect for Dr. Giacconi and his staff and for the high quality of their work is fully shared, I understand, by top NASA officials.

As for the work of our institute council, we have considered policy problems in a number of areas. I will give three examples of actions we have taken. We approved provision of a small fraction—at most, 15 percent—of ST observing time to be assigned by the director of the Science Institute independently of any recommendation by his time allocation committee. We considered the possibility that Science Institute staff might be allotted a disproportionate share of ST time because of the excellence of their proposals, and we proposed that such allocation be comparable with that at other national research centers.

Finally, in consultation with NASA officials and with the endorsement of the space telescope science working group, we recommended that the 3 months allotted to ST science verification be combined with the first 2 months of ST science operation with the various instrument teams in order to obtain some vital scientific results at the earliest possible date.

One of our chief responsibilities is in the field of top personnel for the Science Institute. Several years ago our council selected Riccardo Giacconi as director and Donald Hall as deputy director. Now that Dr. Hall is resigning to accept a position as director of the Institute for Astronomy in Hawaii, our council has carried out an active search for a successor. Dr. Hall, with his outstanding record of scientific research and his skill in high-level scientific administration, was an extremely useful deputy, and our council has looked for candidates with the same somewhat unusual combination of abilities. Several weeks ago we agreed on a short list of possible candidates. In accordance with contractual requirements, the selected individual must be approved by NASA.

Now that the Science Institute is fully staffed and functioning, with the ST launch only 2 years away, it is appropriate to review this enterprise as a whole and the direction in which it is moving. A good framework for review is the set of plans originally prepared by the National Academy committee under the chairmanship of Dr. Donald Hornig. This committee recommended four basic functions for the Science Institute.

Incidentally, if anybody has any questions on the substantive matters that I am discussing, I hope they will feel free to interrupt me at any time. It's much more useful in many ways than to wait until the end.

These four basic functions were as follows: One, planning the scientific program for the space telescope; two, participating with the NASA project in trade-off decisions and design modifications during ST development and refurbishment; three, preparing to monitor ST performance and to process all relevant scientific and engineering data; four, promoting productive participation by visiting scientists and first-rate research by the Institute's staff.

While the second function has been only partially activated, partly because the Science Institute was created late in the ST program, the other three functions which represent more the scientific aspects of the ST program now provide the core program of the Institute, and would seem to correspond very closely indeed with the recommendations of the Hornig committee. Even most of the committee's detailed recommendations in their report have been followed.

The few exceptions include their recommendations for a permanent endowment; for a substantial engineering staff; and for an extended staff of scientists who would divide their time regularly between the Science Institute and their home institution. There is also a significant difference in staff size between the Hornig committee report and the present Institute. I shall return to this difference later.

A key feature of these Hornig committee recommendations which NASA has successfully implemented is the independence of the Science Institute in its scientific operation and planning. The Hornig report stresses, "The quality and independence of the policy board is essential to the success of this enterprise," and concluded that operation of the Science Institute by an independent consortium of universities would be more effective than by other types of organizations more under direct control by NASA.

Let me close with a discussion of the present major problems faced by the Science Institute. There are two problems in particular which I should stress; they are closely related. Both involve budgetary problems and they are naturally of intimate concern to top NASA management. The first is the size of the Institute staff required for the tasks which have been generally approved for the Science Institute, which that Institute is expected to carry out. The second problem is a question of additional tasks which were not included in the initial program but which would undoubtedly increase the effectiveness of space telescope operations. Let me discuss each of these separately.

The staff size envisaged by the Hornig committee was about 100 people. This figure was very provisional; for example, it made no allowance for round-the-clock operation of certain key facilities. Hence, it is not surprising that the actual number of people now known to be required for these necessary activities is about twice the early estimate, though in fact I should point out that it is only 20 percent greater, the number of people now required is 20 percent greater than the estimate in the original AURA proposal for the Space Telescope Science Institute.

One example of increased manpower requirements is provided by the science operation ground systems—usually known as SOGS—for which the detailed software program is being written by a commercial firm, TRW, directly under NASA control. At the start of this TRW effort it was estimated that 85 persons, many working around the clock, would be needed to operate the system which programs the space telescope in detail and carries out routine processing of the scientific data. At the moment it appears that the actual number required for operating SOGS is greater by 30 persons, more nearly 115 rather than 85. Similar manpower increases have occurred in other areas.

After a detailed study of present personnel requirements carried out a year ago, the Institute Council endorsed the need for additional space at the Space Telescope Science Institute. The most immediate, urgent need is for temporary space, available well before the ST launch. After the launch, more permanent space could be provided.

The Council also endorsed the Science Institute recommendation that the necessary additional space be leased from Johns Hopkins University, which would apparently be willing to construct both temporary facilities and, if necessary, a permanent building. NASA has not as yet endorsed this possibility and it is not clear where SOGS personnel will be housed when this system is delivered in a number of months.

Let me turn next to the problem of the possible additional tasks for the Science Institute. There is a very real question as to what the Institute should do to improve the effectiveness of space telescope during the next few years. It is, of course, inevitable that experience and further thought should lead to a number of suggestions for how the effectiveness, overall effectiveness of this very important instrument could be improved.

To quote one example, the Science Institute Visiting Committee—whose chairman, Sandy Faber, will be talking to you in a few days—strongly endorsed at its last meeting the development of an advanced system for accessing science data stored in the Institute archives. Such a system could much improve the availability of these important data for astronomers all over the world. I might say that this item was not included in the original proposal because technology was changing so rapidly that it was felt that any detailed proposal along these lines would be quite obsolete within a few years, so this whole topic technically was postponed to a later date with the thought that a much more effective means would be found for organizing the archives than would have been possible a few years ago.

Such improvements cost money, and even though the sums are very small compared to space telescope costs as a whole, they would probably compete with funds used for other astronomical projects supported by NASA. The space telescope would be very widely used by the astronomical community, but the scientific data obtainable with some of the new instruments which have been proposed would also be important for the general advance of astronomy, even though they might be used by relatively few astronomers compared to ST. As usual, the choice between ultimate uses of scarce fund is difficult.

My own enthusiasm for space telescope remains as high as it has been for some three decades, and I am confident that this instrument will prove for many years one of the most significant and spectacular of any which NASA has launched.

Thank you.

[The prepared statement of Dr. Spitzer follows:]

Statement

by

Lyman Spitzer, Jr.
Charles A. Young Professor of Astronomy, Emeritus
Princeton University

Summary biography of L. Spitzer

Born in Toledo, Ohio, June 26, 1914.

Educated at Yale (B.A., 1935) and Princeton (Ph.D., 1938) Universities.

Yale faculty member, 1939-1947; on leave 1942-46 for World War II undersea warfare research.

Professor of Astronomy, Princeton Univ., 1947-1982; Director, Princeton University Observatory and Chairman of Astronomy Department, 1947-1979.

Started controlled fusion research in plasma physics at Princeton University in 1951, and remained in charge of this work as head of the Plasma Physics Laboratory until 1966.

Principal Investigator for Orbiting Astronomical Observatory No. 3 (Copernicus), which observed ultraviolet stellar spectra from 1972 to 1981.

Author of several technical books on plasma physics and interstellar matter; numerous articles on these topics and on stellar dynamics and space astronomy.

National Medal of Science 1980. Member National Academy of Sciences since 1952.

Chairman since 1981 of AURA's Space Telescope Institute Council, which has administrative oversight of the Space Telescope Science Institute.

Two years ago, on May 24, 1982, I had the privilege of reporting to this same committee concerning the activities of AURA's Space Telescope Institute Council and in particular our discussions of policies and problems relating to the Space Telescope Science Institute. Chairman Volkmer has asked me to report to you again, discussing the development of the Science Institute, especially the matters addressed by our Institute Council.

Let me first review briefly the organization of our Council. As you know, AURA (the Association of Universities for Research in Astronomy) is a consortium of 17 U. S. universities, which manages the National Optical Astronomy Observatories for the NSF as well as the ST Science Institute for NASA. AURA establishes policies for these centers to optimize their effectiveness in providing telescope facilities for visiting astronomers, and interacts with funding agencies and the astronomical community to promote this objective.

Organizationally, the Director of the Science Institute, Dr. Giacconi, reports to the AURA Board of Directors through AURA's President, Dr. John Teem. The ST Institute Council, functioning as a subcommittee of the AURA Board, exercises administrative oversight of the ST Science Institute, partly through frequent consultation with Dr. Giacconi and partly through close contact with the various NASA officials who are involved with the Science Institute program.

Our Council has had an excellent opportunity to follow the development of the Science Institute since its inception in 1980. We have been enormously impressed by what we have seen. Dr. Giacconi, building on the initial organization set up by the Acting Director, Arthur Code, and with vital support by AURA, has assembled a fully outstanding group, with a number of brilliant astronomers. The Institute has developed a deep understanding of the requirements and operational possibilities of the Space Telescope, and has already made many vital contributions to the ST program. This deep respect for Dr. Giacconi and his staff and for the high quality of their work is fully shared by top NASA officials.

As for the work of our Institute Council, we have considered policy problems in a variety of areas. Let me give three examples of actions we have taken. We approved provision of a small fraction (at most 15%) of ST observing time to be assigned by the Director of the Science Institute independently of any recommendation by his Time Allocation committee. We considered the possibility that Science Institute staff might be allotted a disproportionate share of ST time because of the excellence of their proposals, and proposed that such allocation be comparable with that at other national research centers. In consultation with NASA officials, and with the endorsement of the ST Science Working Group, we recommended that the three months allotted to ST Science Verification be combined with the first two months of ST science operation by the various ST instrument teams, in order to obtain some vital scientific results at the earliest possible date.

One of our chief responsibilities is in the field of top personnel for the Science Institute. Several years ago the Institute Council selected Riccardo Giacconi as Director and Donald N. B. Hall as Deputy Director. Since Dr. Hall is resigning to accept a position as Director of the Institute for Astronomy, in Hawaii, our Council has carried out an active search for a successor. Dr. Hall, with his outstanding record of scientific research and his skill in high level scientific administration, was an extremely useful Deputy Director, and our Council has looked for candidates with the same somewhat unusual combination of abilities. Several weeks ago we agreed on a short list of possible candidates; in accordance with contractual requirements the selected individual must be approved by NASA.

Now that the Science Institute is fully staffed and functioning, with the ST launch only two years away, it is appropriate to review this enterprise as a whole and the direction in which it is moving. A good framework for review is the set of plans originally prepared by the National Academy Committee under the chairmanship of Dr. Donald Hornig (Institutional Arrangements for the Space Telescope, 1976). This committee recommended four basic functions for the Science Institute.

1) Planning the scientific program for ST.

2) Participating with the NASA ST project in trade-off decisions and design modifications during ST development and refurbishment.

3) Preparing to monitor ST performance and to process all relevant scientific and engineering data.

4) Promoting productive participation by visiting scientists and first-rate research by its own staff.

While the second function has been only partially activated, partly because the Science Institute was created late in the ST program, the other three functions represent the core program of the Institute, and would seem to correspond closely with the recommendations of the Hornig Committee. Even most of the Committee's detailed recommendations have been followed; the few exceptions include their recommendations for a permanent endowment, a substantial engineering staff and an "extended staff", scientists who would divide their time regularly between the Science Institute and their home institution. There is also a significant difference in staff size between the Hornig Committee report and the actual Science Institute; I shall return to this difference later.

A key feature of the Hornig Committee recommendation, which NASA has successfully implemented, is the independence of the Science Institute in its scientific operation and planning. The report stresses that "the quality and independence of the policy board is essential to the success of this enterprise", and concludes that operation of the Science Institute by an independent consortium of universities would be more effective than by other types of organizations which would be more under direct control by NASA.

Let me close with a discussion of the present major problems faced by the Science Institute. There are two in particular which I should stress, and they are closely related. Both involve budgetary problems and hence are of intimate concern to top NASA management. The first is the size of the Institute staff required for the generally approved tasks which the Science Institute has been expected to carry out. The second is the question of additional tasks which were not included in the initial program, but which would increase the effectiveness of ST operations.

The staff size envisaged by the Hornig Committee was about 90 at launch, increasing to about 120 within a year or two after launch. These figures were very provisional; for example, they made no allowance for round-the-clock operation of certain key facilities. Thus it is not surprising that the actual number of people now known to be required for the necessary activities is about twice these early estimates, though only 20 percent greater than the manpower estimate in the original AURA proposal for the ST ScI. One example of increased manpower requirements is provided by the Science Operations Ground System (SOGS), for which the detailed software program is being written by a commercial firm (TRW) directly for NASA. At the start of this effort, it was estimated that 85 persons (many working on around-the-clock shifts) would be needed to operate the system, which programs the ST in detail and carries out routine processing of the scientific data. Now it appears that the actual number is greater by some 30 persons. Similar manpower increases have occurred in other areas.

After a detailed study, carried out a year ago, the Institute Council endorsed the need for additional space at the ST Science Institute. The most immediate need is for temporary space, available well before ST launch, after which more permanent space could be provided. The Council also endorsed the ScI recommendation that the necessary additional space be leased from Johns Hopkins University, which would apparently be willing to construct both temporary facilities and a permanent building. NASA has not as yet endorsed this possibility, and it is not clear where SOGS personnel will be housed when this system is delivered in a number of months.

There is also a question as to what the Science Institute should do to improve the effectiveness of ST during the next few years. For example, the ScI Visiting Committee strongly endorsed the development of an advanced system for accessing science data stored in the Institute archives, since such a system would much improve the availability of these important data for astronomers all over the world. Such improvements cost money, and while the sums are small compared to the ST costs as a whole, they would compete with funds used for other astronomical projects supported by NASA. The Space Telescope would be very widely used by the astronomical community, but the scientific data obtainable with some of the new instruments which have been proposed would be important for the general advance of astronomy, even if used by relatively few astronomers compared to ST. As usual, a choice between alternate uses of scarce funds is difficult.

My own enthusiasm for ST remains as high as it has been for some three decades, and I am confident that this instrument will prove for many years one of the most significant and spectacular of any which NASA has launched.

Mr. VOLKMER. Thank you very much, Dr. Spitzer.
Dr. Field?

STATEMENT OF DR. GEORGE B. FIELD, CENTER FOR ASTROPHYSICS, CAMBRIDGE, MA, AND CHAIRMAN, SPACE TELESCOPE INSTITUTE ADVISORY COMMITTEE

Dr. FIELD. Mr. Chairman, it is a pleasure to appear before this subcommittee, which has been so supportive of space science in general, and the Hubble space telescope—which I will refer to as ST—in general.

I am speaking from the perspective of the Deputy Chair of the Space Telescope Advisory Committee, which I will refer to as STAC, which reports to the director of the Space Telescope Science Institute. This committee, I should say, has some 12 to 15 members and the chairman is Dr. Malcolm Longaire, Astronomer Royal of Scotland.

The committee advises the director of STSI on some of the very issues which you have asked me to review today: the potential of ST to meet the needs of the community, the prioritization of science objectives, the optimum scientific use of ST, and the scope of responsibilities of and the relationship of the science community to STSI. I should say that this committee has been in existence only about 6 months and we have had two meetings.

Already several things have become clear to this committee. Let me address first the philosophy. The space telescope represents an extremely precious resource for astronomical research. As evidence for this statement, I refer to the results of a questionnaire which STSI has recently circulated to a large number of astronomers in an attempt to assess the degree of interest in using ST, and may I say the number of astronomers who were contacted is 7,500. So far, 3,000 replies have been received from the 7,500 persons contacted, and on the basis of these replies it has been estimated that there will be of the order of magnitude of 2,300 proposals per year to use space telescope.

Now I should say at this point that as a scientist, I should give an estimate of the accuracy of this figure, and I would have to say that at this point we have to regard this as an extremely uncertain figure because naturally scientists receiving this questionnaire, having to guess what their scientific program will be 2 or 3 years in the future, they can only estimate very roughly. Nevertheless, this number is so large that there is no doubt in my mind or in the minds of the staff of the Institute that there will be a very large requirement or a very large request to use the Space Telescope, and very likely far more than can be accommodated.

Very specifically, the Institute staff has made an attempt to assess the responses to the questionnaire in more detail to get an estimate of the total amount of observing time that would be requested—again, extremely uncertain, but perhaps as much as 10 or 20 times the amount that will be available. It is, therefore, already clear that ST will be in very great demand and that only a small fraction of all the potential projects may be accommodated.

Given this situation, the criteria and the process by which scientific groups are selected to carry out projects on ST become para-

mount. The philosophy which guides the Space Telescope Institute in this situation is that of the deeply ingrained belief throughout the scientific community that the selection must be carried out by peer review, and all of the planning is based on that principle.

Let me turn now to the science objectives of the Space Telescope. As you know, ST has a wide range of observational capabilities throughout the ultraviolet and optical wave length ranges and, as a result, practically every problem in astronomy, ranging from the planets to the galaxies, can be addressed by the space telescope. This qualitative assertion is supported by the fact that the responses to the questionnaires indeed covered every aspect of astronomy.

Now as the Institute tries to design a system for giving an adequate peer review to the many hundreds, if not thousands, of proposals to be received covering a wide range of astronomical specialties, it is clear that there must be a very detailed and complex plan to deal with this system every few months. In particular, STSI plans to establish what they call a Time Allocation Committee, or TAC, which is broadly representative of the specialties within astronomy. I should say that this method of dealing with such a situation is quite common throughout astronomy at various observatories.

Proposals for use of the space telescope will be categorized by subdiscipline and they will each be ranked in priority on the basis of well-established criteria by panels of specialists within TAC. Let me explain that a little further: It is anticipated that TAC will have subpanels in each of the various specialities of astronomy, and each proposal will be referred to one of those subpanels for assessment.

Because it is especially difficult and important to fairly compare projects within quite different subdisciplines, TAC as a whole, including the chairs of the subdiscipline panels and additional members-at-large, will review the rankings of each panel and will form a master list of all proposed projects prioritized according to the preestablished criteria. This list will then be recommended by TAC to the director of STSI for implementation. I believe it is a contractual matter that he has the final authority to allocate the observing time on ST.

It is too early at this point to state exactly what the criteria for judging proposals will be. That is a matter for discussion at the Institute at the present time. However, it is certain that the selection criteria will emphasize the effective use of the unique capabilities of ST to address important problems in astronomy.

Now let me turn to something which is a little unusual in the assignment of observing time at observatories funded by the Government so far. The committee of which I am the Vice Chair, STAC, has been discussing a certain class of research problems which are likely to lead to what might be called key projects. An example of such is the Distance Scale of the Universe. This problem is important because it reflects directly on many other research problems within astronomy. It is also a very large problem because it will take coordinated efforts on the part of several different specialists as well as a large amount of observing time on space telescope.

So one may define a key project in general as one of outstanding scientific importance which can be carried out with ST and requires ST for its completion, which requires a substantial fraction of the available observing time on ST and requires a substantial degree of coordination among scientific groups for its successful completion. At this point STAC is discussing key projects as defined in this way.

As I said, it has not been traditional in optical astronomy to separate out such key projects for special treatment. STAC, however, believes that it is necessary to do so with the space telescope because the ST is a uniquely powerful instrument, capable of a definitive attack on certain difficult problems which have broad impact in astronomy. STAC believes that the opportunity to attack such problems should not be lost and that key projects should be carried out even if they do require a substantial fraction of the observing time.

As I said, STAC believes that special protection should be afforded within the ST program for key projects. In particular, while the bulk of the observing time will be reserved for small- and medium-size projects, a small fraction of the time—which is currently estimated roughly to be about 30 percent—should be set aside so that progress can be made on key projects. Although this fraction of the time is by no means a majority of the time on ST, it is vitally important that it be used only for the highest quality proposals. Special attention is now being given to how key projects are to be identified and how proposals to carry them out should be evaluated.

As a little background here, I would say that this matter is one where the community is only now becoming involved, and I believe there will be significant debate on this whole matter in the next few months.

Selection of key projects: In view of the importance of key projects to astronomy and the fact that substantial amounts of observing time are required, STAC has recommended that the entire astronomical community be involved in identifying such key projects. STSI is now planning to appoint five working groups of astronomers in various subdisciplines that are listed in my statement, and they will be charged with identifying candidates for key projects, estimating the observing time required, and putting them into priority order. On the basis of the reports of the working groups, STAC will recommend a list of key projects to the Director.

Let me make clear at this point that it is by no means the purpose of this to identify the personnel or the successful proposers for such projects, but only to identify what key projects might be in order that the community at large may propose to do them.

Proposals for observing time: The opportunity to propose for observing time on ST will be available to astronomers from all countries. The announcement of opportunity for such proposals will cover both general observing and key projects as explained above. Proposals in the latter category will be judged against more specific criteria which will be established by STSI on the basis of the information from the working groups. In the first 2½ years of operation of ST, it is planned that substantial progress can be accomplished on a few key projects as well as on a large number of individual projects.

Finally, let me comment briefly on the relationship of the science community to STSI. STSI will succeed only insofar as it serves the needs of the scientific community. My own personal perception is that every effort is being made by STSI at the present time to serve the community well and, further—and this is important—to explain its role to the community. This is done through a variety of committees like the Space Telescope Institute Committee, of which Lyman Spitzer is chairman, STAC, the committee on which I serve, the visiting committee, from whom you will hear, and other committees, also through public communications like the questionnaire and newsletter and so forth.

I think that as the key project concept is discussed in the community, the relationship between STSI and the community will be further exercised—perhaps that is a correct choice of words—and as the working groups are appointed and get to work and the criteria for successful proposals for general observing and key project observing are developed and disseminated, there will be a lot more discussion in the community. No doubt there will be much discussion as these events unfold which will be educational for both the Institute and the community.

As Vice Chair of—I should have said, and I want to amend the record at this point—Vice Chair of STAC, not STSI, I intend to work toward that goal.

Thank you.

[The prepared statement of Dr. Field follows:]

BIOGRAPHICAL SKETCH OF DR. GEORGE B. FIELD

Dr. Field is a theoretical astrophysicist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, where he serves as Senior Physicist and Robert Wheeler Willson Professor of Applied Astronomy. His current research interests are solar magnetohydrodynamics and the process of galaxy formation. Dr. Field has served on numerous committees, including several related to the Hubble Space Telescope; he is now Vice Chair of the Space Telescope Advisory Committee of the Space Telescope Science Institute. He also served as Chairman of the Astronomy Survey Committee of the National Academy of Sciences - National Research Council, whose report "Astronomy and Astrophysics for the 1980's" is being used by NASA and NSF in planning programs for the current decade.

TESTIMONY OF DR. GEORGE FIELD

TO

HOUSE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS

THE HUBBLE SPACE TELESCOPE AND THE ASTRONOMICAL COMMUNITY

May 22, 1984

INTRODUCTION

It is a pleasure to appear before this Subcommittee, which has been so supportive of space science in general, and the Hubble Space Telescope (ST) in particular. I will speak from the perspective of the Deputy Chair of the Space Telescope Advisory Committee (STAC) of the Space Telescope Science Institute (STScI). This Committee advises the Director of STScI on some of the issues which you have asked me to review: the potential of ST to meet the needs of the community, the prioritization of science objectives, the optimum scientific use of ST, and the scope of responsibilities of and the relationship of the science community to STScI.

PHILOSOPHY

The ST represents an extremely precious resource for astronomical research. As evidence for this statement I refer to the results of a questionnaire which STScI has recently circulated to a large number of astronomers in an attempt to assess the degree of interest in using ST. So far, 3000 replies have been received; it has been estimated from

these replies that there will be 2300 proposals per year to use ST. When the projects mentioned by the respondents are assessed in more detail, it is estimated that the amount of observing time requested will be 10 to 20 times greater than the time available. It is therefore already clear that ST will be in very great demand, and that only a small fraction of all potential projects may be accommodated.

Given this situation, the criteria and the process by which scientific groups are selected to carry out projects become paramount. It is a deeply ingrained belief in the scientific community that in such a situation, the selection must be carried out by peer review, and this principle is at the basis of the planning at STScI.

SCIENCE OBJECTIVES

ST has a wide range of observational capabilities throughout the ultraviolet and optical wavelength ranges, and as a result, practically all problems in astronomy, ranging from motions in the atmospheres of the planets to the stellar composition of distant galaxies, can be addressed by ST. This is supported by the fact that scientists responding to the STScI questionnaires expressed interest in observing objects representing every facet of current astronomical research.

It follows that the peer review process must be able to handle proposals covering a large range of astronomical specialties. Currently, STScI is planning to establish a Time Allocation Committee (TAC) which is broadly representative of the specialties within astronomy. Proposals for use of ST will be categorized by subdiscipline, and ranked in priority on the basis of well-established criteria by panels of specialists within TAC.

Because it is especially difficult and important to fairly compare projects within quite different subdisciplines, TAC as a whole, including the chairs of the subdiscipline panels and additional members at large, will review the rankings by each panel, and will form a master list of all proposed projects prioritized according to the preestablished criteria. This list will be recommended to the Director of STScI for implementation. He has the final authority to allocate observing time.

It is too early to state exactly what the criteria for judging proposals will be. However, it is certain that the selection criteria will heavily emphasize the effective use of the unique capabilities of ST to address important problems in astronomy.

KEY PROJECTS

STAC has been discussing how to handle certain research problems, like the distance scale of the Universe, which are likely to lead to what might be called "key projects" on ST. Such key projects may be defined as those of outstanding scientific importance to carry out with ST, requiring a substantial fraction of the available observing time on ST, and requiring a substantial degree of coordination among scientific groups for their successful completion.

It has not been traditional in optical astronomy to treat potential key projects in a special way. The need to do so with ST reflects the fact that ST is a uniquely powerful instrument, capable of a definitive attack on certain difficult problems of broad interest. STAC believes that the opportunity to do so should not be lost, and that key projects should be carried out even if to do so may require a substantial fraction of the observing time.

STAC believes that special protection should be afforded within the ST program for key projects. In particular, while the bulk of the observing time will be reserved for small and medium-size projects, a small fraction of the time (say 30%) should be set aside so that progress can be made on key projects. Although this fraction of time is by no means a majority of the time on ST, it is vitally important that it be used only for the highest quality proposals. Special attention is now being given to how key projects are to be identified, and how proposals to carry them out should be evaluated.

SELECTION OF KEY PROJECTS

In view of the importance of key projects to astronomy and the fact that substantial amounts of observing time are required, STAC has recommended that the entire astronomical community be involved in identifying key projects. STScI is now planning to appoint five Working Groups of astronomers (Planetary Astronomy, Stars and Star Clusters in our Galaxy, Galaxies and Clusters of Galaxies, Interstellar and Intergalactic Matter, and Quasars and Active Galactic Nuclei) who will be charged with identifying candidates for key projects, estimating the observing time required, and putting them into priority order. On the basis of the reports of the Working Groups, STAC will recommend a list of key projects to the Director.

PROPOSALS FOR OBSERVING TIME

The opportunity to propose for observing time on ST will be available to astronomers from all countries. The announcement of opportunity for such proposals will cover both general observing and

the key projects as explained above; proposals for the latter category of activity will be judged against more specific criteria, established by STScI on the basis of information from the Working Groups. In the first 2.5 years of operation of ST it is planned that substantial progress can be accomplished on a few key projects, as well as on a large number of individual projects.

RELATIONSHIP TO THE SCIENCE COMMUNITY OF STScI

STScI will succeed only in so far as it serves the needs of the community. My perception is that every effort is being made by STScI management to serve the community well, and further, to explain its role to the community. This is being done through committees like the Space Telescope Institute Council (STIC), STAC, the Visiting Committee and other committees, and also through public communications like the questionnaire referred to above, a newsletter, and presentations at professional meetings. STScI - community relationship will be further exercised as the key project concept is publicized, the Working Groups are appointed and get to work, and the criteria for successful proposals for general observing and key project observing are developed and disseminated. No doubt there will be much discussion as these events unfold, which will be educational for both STScI and the community. As Vice Chair of ~~STScI~~ STAC, I intend to work toward that goal.

Mr. BROWN [acting chairman]. Thank you very much, Dr. Field and Dr. Spitzer. The chairman apologizes for his temporary absence, and he will be back shortly.

Dr. Spitzer, you made the interesting comment that you had been fascinated by this for 30 years. Is it possible that you are a science fiction aficionado like I am?

Dr. SPITZER. Yes.

Mr. BROWN. Because we didn't have a space program 30 years ago?

Dr. SPITZER. Oh, no, not at all. I was an ardent reader of science fiction stories when I was in high school, and maintained it for quite a few years.

Mr. BROWN. Did you actually predict the possibility of a space telescope as an instrument for the astronomical community that long ago?

Dr. SPITZER. In 1947, I wrote a brief paper on the possibilities of observing the stars and the planets with telescopes of different sizes above the atmosphere, so that was actually almost 40 years ago.

Mr. BROWN. You were sort of a contemporary of Arthur Clark, who envisioned the application to communications about that time, also.

Dr. SPITZER. Well, Herman Oberth, of course, also discussed it in his book on rockets heaven knows how long ago—long before the war—but he was not an astronomer.

Mr. BROWN. I had an opportunity to meet Heinlein last month, whom I read for years and I never had a chance to meet him. I finally got to see him. We differ in our political philosophy but he still writes good science fiction. [Laughter.]

You made some reference, also, to the fact that there were few areas in which recommendations which had been made by the—is it the Hornig committee? The exceptions that you referred to——

Dr. SPITZER. Yes.

Mr. BROWN [continuing]. Referred to the recommendations for a permanent endowment, the engineering staff, and so forth. I was particularly intrigued by the permanent endowment proposal. Was that intended to be a Government-financed endowment or a privately financed?

Dr. SPITZER. Oh, no, no, private. The suggestion was that the consortium that was running the Science Institute would go to foundations and private individuals and try to build up a private endowment from private sources to give some additional stability for some aspects and to help the Institute do some things that perhaps NASA might feel were inappropriate for Government funds.

Mr. BROWN. That is typical of the way some of our earliest astronomical observatories were funded.

Dr. SPITZER. Yes.

Mr. BROWN. Could you describe for me the reasons why that evoked a negative reaction?

Dr. SPITZER. I don't think it evoked such a strong negative reaction. It was just that there hasn't been any very positive push in that direction. So much of what the Institute is doing is supported by NASA, that it isn't—the Science Institute hasn't yet been able

to get a clear picture of what private funds could do, with which they could approach the private sector.

Dr. Giacconi has a very active interest in raising funds for the Science Institute, and talks about setting up science associates of the Science Institute, corporations who would give annual funds. That is still under—in the planning stage but at the moment it hasn't gotten very far. I don't think NASA opposes it particularly. They haven't shown any great enthusiasm for it because—it may be for fear that it would divert attention at the Science Institute from their more important functions that NASA was supporting. I don't know.

Mr. BROWN. Well, I am a little shocked by that. I think maybe that was a tactical matter rather than a teaching matter.

Dr. SPITZER. It could well be.

Mr. BROWN. You know, I have taken an interest in the funding of that amateur operation out in California, MIRA, and they have had to go almost exclusively to private sources for funding. Of course, they are not quite in the same category as the space telescope but they are apparently very eager young astronomers trying to make a contribution in the field, and I think it's healthy that we make some effort to involve the private community in the financing of some of these things.

On that aspect, Dr. Field, you made reference to the various efforts to fully involve the astronomical community, the publicizing of what is going on there and so forth. Is that concern for maintaining a full communication extend to the public at large, because of course one of our concerns in the Congress and in this committee is to maintain an adequate base of public understanding of major scientific areas, so that when we go home at least one or two constituents will say, "My, I'm glad you funded that space telescope," or something like that. Do you see any component of your program that would help us to achieve that sort of thing?

Dr. FIELD. Mr. Brown, I agree with you that that's important. I believe that the Hornig committee suggested that there be an effort on behalf of the Institute of doing just that. I believe also that there is a public information officer at the Institute who is charged with communicating the activities of the Institute and the space telescope to the public. I cannot give you any detailed information as to the scope of that program at the present time. Perhaps Lyman can.

Dr. SPITZER. If I could add a little bit to that, the Science Institute has made a specific proposal to NASA for expanding its public information office with four or five people and facilities for videotaping and one thing or another. This, however, all represents an increase over the original contract. NASA is viewing all those proposed increases together. They are under strong——They feel under strong pressure not to allow any increases, even if they have to, and it isn't clear how much of that recommended increase—— [1]

Mr. BROWN. Well, I can understand that as a short-range tactic, also, but as you undoubtedly know, in many of our major space installations we have moved in the direction of abandoning the

[1] The witness edits this remark to read: "They feel under strong pressure not to allow any increases, and it isn't clear how much of that recommended increase——"

public information program, even to the extent of setting up public education facilities and that sort of thing. It seems to me both desirable and inevitable that we should take advantage of the tremendous educational potential to tell us—I mean, to disseminate information to the public.

But on the general question that you raised, Dr. Field, about the large amount of interest in the astronomical community, and of course your community probably—maybe because of its small size—has done a better job of involving its members in planning for the future, future directions of astronomical science, than any of the larger disciplines such as physics and chemistry—in my opinion, anyway, and I may be prejudiced.

What kind of planning, if any, has been done for, we will say, future generation efforts? That is, certainly we are not—we can't put the space telescope up there, see if it works, let it die out, and be left without facilities in space. We have other, more limited facilities, of course, which have proven to be extremely valuable also, but even several years ago here in this committee I raised the question of, isn't it possible that the scientific community and the astronomical community, particularly looking at the needs in Europe and other places, might not support an additional facility such as the space telescope. Certainly we want to be thinking about what we will do when this one begins to end its useful life. Has your committee given thought to that?

Dr. FIELD. Yes, Mr. Brown. I think you may be referring to a committee that we discussed briefly this morning, the Astronomy Survey Committee of the National Academy.

Mr. BROWN. That's right. I am referring to that.

Dr. FIELD. As you know, that committee was charged with planning for a very specific time period, and we did in fact recommend facilities for that time period.

Mr. BROWN. That was just for the eighties.

Dr. FIELD. Just for the eighties.

Mr. BROWN. That's a very short period.

Dr. FIELD. Just a very short period of time, that's right.

Mr. BROWN. Astronomy ought to be thinking in longer time periods.

Dr. FIELD. It ought to and, recognizing that, we did. There is a chapter in the report which relates to beyond the 1980's. Specifically, we did anticipate that the space telescope and the other facilities of the eighties will be a first step toward a large, extremely powerful set of facilities in orbit to commence in the 1990's. We are thinking not only would it be possible to mount an aggressive program of observations across the entire electromagnetic spectrum—and I am referring here to x rays and to infrared as well as to ultraviolet and optical, which is the main purpose of ST—but also the possibility, which I think may seem even more real now since the repair of SMM, of actively involving astronauts in a construction role to build really large telescopes. As you are aware, ST is a major telescope but it still falls short of what could, in principle, be utilized by the astronomical community. We are thinking of something in the class of 5 or even 10 meters, so if things go well one can think in terms of that, and our committee did address those concerns in its report.

Mr. BROWN. Of course, this is an ideal kind of a project to be handled on a cooperative basis with other countries. Possibly even the Soviets would be interested in this, if we ever get to the point where we can discuss cooperation with them.

Dr. FIELD. Yes; I think that's right. I had the pleasure of meeting with the head of the Soviet Space Institute in Moscow just last week, and he expressed the view——

Mr. BROWN. He was in Washington, I believe, last week.

Dr. FIELD. Yes; and he was also in Boston. He made a quick transition.

Perhaps you had a similar discussion, but he does regret that the conversations have been at a lower level in the past few years, and expressed great interest in collaborative programs. I think there are some specific suggestions along that line.

But as to your general point that space astronomy could be or should be international, I would agree and recall to you that the space telescope project itself is international; that the European Community has made a contribution, I believe, of 15 percent; and that it is sharing fully in the opportunity of using the space telescope as well as in the operation of the Space Telescope Institute.

Mr. BROWN. Well, that's to be highly commended, but I would point out that Dr. Beggs, in his trip to Europe just a few weeks ago seeking European cooperation on the space station, had set a target, as I recall the newspaper stories, of possibly 25 percent involvement, and that certainly in future generations of the space telescope I think we should look beyond a 15 percent involvement very readily, since that community could hope to get considerably more than that in terms of use of the facility.

I have been pursuing items of special interest to me, but I am sure the chairman has some questions that relate to our more specific oversight functions, and I will yield back the balance of my time.

Mr. VOLKMER. I thank the gentleman from California. I thank him for sitting in while I had to step out for a little bit.

Now at this time I would like to recognize the gentleman from New Mexico for a statement, who has now joined us, the ranking minority member.

Mr. LUJAN. Thank you, Mr. Chairman. I simply want to ask unanimous consent to include a statement in the record.

Mr. VOLKMER. Without objection, so ordered.

[The prepared statement of Mr. Lujan follows:]

HONORABLE MANUEL LUJAN, JR.
HEARING TO REVIEW SPACE TELESCOPE COST, SCHEDULE AND PERFORMANCE
MAY 22, 1984

THANK YOU, MR. CHAIRMAN. I AM PLEASED THAT THIS SUBCOMMITTEE HAS CONTINUED TO BE A STRONG SUPPORTER OF THE SPACE TELESCOPE, IN SPITE OF THE PROBLEMS THE PROGRAM HAS HAD. LAST YEAR WE WERE DISMAYED TO LEARN THAT THE SPACE TELESCOPE WAS GOING TO BE DELAYED AND COST MUCH MORE THAN ORIGINALLY THOUGHT. WE HELD HEARINGS THEN TO BETTER UNDERSTAND THE NATURE OF THESE PROBLEMS. IT APPEARS THAT THESE PROBLEMS ARE BEING RESOLVED -- HOPEFULLY WITH NO MORE DELAYS AND COST OVERRUNS. IN FACT, I BELIEVE EVERY ONE HERE TODAY WANTS TO BE REASSURED THAT WE ARE NOW BRISKLY WALKING DOWN THE ROAD TO SUCCESS. THE FACT THAT THE SPACE TELESCOPE PROMISES TO REVOLUTIONIZE THE FIELD OF ASTRONOMY MAKES US ESPECIALLY EAGER TO SEE IT LAUNCHED SUCCESSFULLY. THE FACT THAT WE WILL HAVE A LARGE, HIGH QUALITY TELESCOPE IN ORBIT, FREE FROM THE DISTORTION OF THE EARTH'S ATMOSPHERE, MEANS THAT WE WILL SUDDENLY BE ABLE TO SEE THINGS THAT COULD NEVER BE SEEN ON EARTH, AND A NEW ERA OF SCIENCE WILL BEGIN.

BUT IN ANOTHER WAY THE SPACE TELESCOPE MARKS A NEW ERA IN SCIENCE. PERHAPS THE REPAIR OF THE SOLAR MAXIMUM MISSION WAS REALLY THE STARTING POINT OF THIS NEW ERA BECAUSE IT SHOWS THE FEASIBILITY OF "PERMANENT" OBSERVATORIES IN SPACE THAT CAN BE SERVICED AND REPAIRED IN ORBIT. IN FACT, THESE NEW FACILITIES IN SPACE CAN BE UPGRADED IN ORBIT SINCE THEY HAVE BEEN DESIGNED TO ALLOW REPLACEMENT OF INSTRUMENTS WITH NEWER VERSIONS AT SOME POINT IN TIME. IT IS CHEAPER AND LESS RISKY TO REPAIR OR REFURBISH IN ORBIT THAN TO BRING THE FACILITY BACK TO EARTH, OR TO LAUNCH A NEW ONE BUILT FROM SCRATCH. OF COURSE, THIS IS ANOTHER AREA WHERE THE SPACE STATION WILL PLAY AN IMPORTANT ROLE. THESE CAPABILITIES WILL HAVE GREAT IMPLICATIONS IN REGARD TO NOT ONLY THE COST AND DESIGN, BUT THE INSTITUTIONAL STRUCTURE AS WELL.

CLEARLY A MORE PERMANENT FACILITY GIVES SCIENTISTS A LARGER ROLE THAN BEFORE IN THE SPACE SCIENCE PROGRAMS, WHICH HAVE BEEN DOMINATED BY ENGINEERS AT NASA. THE SCIENCE INSTITUTE WILL SERVE AS A FOCAL POINT FOR SCIENTISTS FROM ALL OVER THE WORLD. HOWEVER, IT IS NOT CLEAR TO ME THAT THE SCIENTISTS WILL ACTUALLY HAVE TO PHYSICALLY BE AT THE SCIENCE INSTITUTE. THE RECENT EXAMPLE OF THE INTERNATIONAL ULTRAVIOLET EXPLORER MAY SET THE RIGHT PRECEDENT FOR THE FUTURE BECAUSE IN THAT PROGRAM SCIENTISTS HAVE TAKEN ADVANTAGE OF THE RECENT ADVANCES IN COMPUTER AND COMMUNICATIONS CAPABILITIES SUCH THAT THEY CAN REMAIN AT THEIR OWN UNIVERSITIES OR OTHER INSTITUTIONS AND INTERACT WITH THE OBSERVING FACILITY VERY EFFECTIVELY. THIS WOULD BE AN EXCITING WAY TO ENCOURAGE WIDER USE OF THE DATA AT THE SAME TIME WE SAVE MONEY.

THERE IS ANOTHER REASON SUCH AN APPROACH INTERESTS ME. ALL TOO OFTEN I HAVE SEEN A RESEARCH FACILITY ESTABLISHED TO SUPPORT A GOVERNMENT PROGRAM, ONLY TO LATER FIND WE ARE ESTABLISHING GOVERNMENT PROGRAMS TO SUPPORT THE FACILITY. THAT IS, ALL TOO OFTEN FACILITIES TAKE ON A LIFE OF THEIR OWN, REQUIRING CONTINUED FUNDING LONG AFTER THEIR ORIGINAL PURPOSE IS GONE. IN FACT, IT IS USUALLY THE CASE THAT THE SIZE OF THE FACILITY AND THE SCOPE OF ITS RESPONSIBILITIES WILL GROW. WE CANNOT AFFORD TO ESTABLISH A NEW INSTITUTION, THAT MUST BE CONTINUED, WITH EVERY FACILITY WE LAUNCH.

SO I AM HOPING TO BE REASSURED TODAY, AND THURSDAY, THAT NOT ONLY WILL EVERYTHING BE DONE ON SCHEDULE AND ON BUDGET, BUT THAT A MAINTENANCE PLAN WILL PREVENT UNREASONABLY LONG DOWN TIMES AND THAT THE RESULTS WILL BE VALUABLE AND FLEXIBLE RESEARCH TOOLS.

THANK YOU, MR. CHAIRMAN.

Mr. VOLKMER. I would like to ask a few of the, I guess, more basic questions as far as this committee is concerned, as some of the basic background kind of thing, where do we go from here and maybe what's going to be the most of the total as we go on, and what are we looking at as far as additional costs in the future.

Now I would like to first get back to, I guess, one of the basics as to what actually led to the process whereby we ended up with a separate institute, the Science Institute, to manage the science operations on the space telescope. Anybody want to answer that? It doesn't make any difference. Go ahead, either one of you.

Dr. SPITZER. Yes; there were an ongoing series of committees within NASA to push for the space telescope under different chairmen at different times. Nancy Roman was in charge of a committee that was pushing studies of the space telescope, and then Bob O'Dell took her place.

At one stage in the course of these committee investigations we discussed what should be the organization of the scientific operation, and I was a member of a committee that was charged with the responsibility of considering that topic. We prepared a memorandum based on the experience that we had had with other space telescopes, particularly the Wisconsin Orbiting Astronomical Observatory, which Bob Bless here represents, and the Copernicus satellite of Princeton which I was associated with.

On the basis of those experiences and also the experiences with large national facilities in astronomy and physics which are run by consortia of universities, we recommended an organization in which NASA would retain the main responsibility for the actual

generation of commands for the space telescope, but a separate organization under a consortia of universities or some other nonprofit institution would be responsible for the detailed scientific planning as to what would be observed and when.

The report of this committee was circulated to other committees who considered it. NASA then asked the Academy to set up a special committee to consider how the scientific operation of the space telescope should be organized. That was the Hornig committee that submitted its report. There was then a full-dress NASA Committee that reconsidered the issue, and it continued to grow, and the astronomers at least were all enthusiastic and many people within NASA were enthusiastic, and that's what was finally agreed upon. It had a gradual, slow growth.

Dr. FIELD. Mr. Chairman, maybe I could add briefly that in approximately the same time period, perhaps a little earlier, the Greenstein committee which issued a report in 1972 concerning the facilities for astronomy in the 1970's had a section on the space telescope, and in there it also recommended that there be an independent institute to run the space telescope.

Mr. VOLKMER. Now the Hornig report was written in 1976.

Dr. SPITZER. It was published in 1976.

Mr. VOLKMER. It was published, right, and at the time would you be—well, let's put it this way: Would you be willing to compare NASA's support for the needs of science and astronomy presently and as it was in 1976?

Dr. FIELD. I'm not sure what you're getting at, Mr. Chairman. Are you referring to dollar figures or something of that nature?

Mr. VOLKMER. Well, not only dollar figures but support of projects for the future and the present, where we were in 1976 versus where we are now.

Dr. FIELD. My overall statement would be that NASA has aggressively pursued the opportunities of space astronomy, both in that period and in this period.

Dr. SPITZER. In 1976 they were pushing the orbiting astronomical observatories, which at that time were very pioneering, advanced. Now, in retrospect, of course, those seem a little old fashioned. We are now pushing for the space telescope and other things.

Mr. VOLKMER. Well, maybe 10 years from now we will maybe look back and say, "Why didn't we do it a little different, too," or add a little more or change this or that, but we learn knowledge as we go along.

The other thing, to get back, continue with the Hornig report, as I understand it recommended somewhere between 100 and 120 personnel.

Dr. SPITZER. Yes; I think it was 90 at the time of the launch and 120 a few years later.

Mr. VOLKMER. Right. Now we're talking about figures quite a bit higher; are we not?

Dr. SPITZER. That's correct.

Mr. VOLKMER. What would be—let's put it this way—in the present configuration of the Institute and scientists who are participating, et cetera, what would be the number of astronomers that would be actually with the Science Institute?

Dr. SPITZER. The number of Ph.D. astronomers?

Mr. VOLKMER. Yes.

Dr. SPITZER. That hasn't changed so much: in the order of 30, 35 astronomers with Ph.D.'s doing research.

Mr. VOLKMER. Then where is the growth?

Dr. SPITZER. The growth? Well, for one thing, there is a lot of growth in the operators for the complicated software systems required for running the space telescope—programming it, routine processing of the data. That was the SOGS program that I referred to. The Hornig committee made no allowance for round-the-clock operation. When you have round-the-clock operation you have five times as many people as for just an 8-hour shift, 5 days a week.

Mr. VOLKMER. What we're basically talking about is our computer management type personnel, programmers——

Dr. SPITZER. Yes, in part, in part, but there have been other increases. If, for example, you take the present Science Institute recommendations for what they feel is the optimum program, it includes for example a staff of five—as I was commenting a little earlier to Mr. Brown—for the public information office. This was not part of the authorized program, and so it represents an increase. Then there is another increase for the improvement of the data archives so they will be more generally available, and there are other improvements.

The SOGS system, as it was being built by TRW, really made no allowance for following planets. That's much more difficult because planets move with respect to the stars, and that is entirely different, and it just hasn't been included in what SOGS has been—in the way SOGS is now being built, so there has to be a post-SOGS Program of development for controlling the space telescope so that it can look at a particular area on Jupiter for several hours and follow it while Jupiter rotates and moves with respect to the stars. That all costs money and takes more people.

Mr. VOLKMER. In other words, there's going to have to be some changes made in the proposed SOGS Program by TRW.

Dr. SPITZER. Either by TRW or by Institute staff or by some other contractor. Everybody agrees it's necessary but just who will do it has not yet been—it will have to be supervised by——

Mr. VOLKMER. Are there any other difficulties that you see in development of the software for the SOGS Program?

Dr. SPITZER. No; it's mainly for the planets but there is also difficulty in the use of the space telescope for what is called astrometry—measurement of the precise positions of stars with respect to each other. This is done in principle with the fine guidance sensors that Perkin-Elmer has been building. The data for those fine guidance sensors is regarded by the engineering staff as engineering data, so it doesn't really get into the SOGS system at a place where it's useful and at the moment there is no—the output of SOGS doesn't include data that the astrometrists can really use. So in addition to modifying SOGS to follow the planets, we also have to modify SOGS to include the astrometric data. Those are the two main modifications that have to be made.

Mr. VOLKMER. All right. Now, should there be an upper limit on personnel at the Science Institute?

Dr. SPITZER. I would think that there would be—that there is a limit on what NASA can afford to spend and the number of people

that can be supported. I would assume that such a limit would be set after a study of what the present staff has to be to carry out the functions and a study of what modifications—what amplifications in the direction of public information offices and other things—are required. As you probably know, NASA has asked the National Academy to set up a new committee just to consider the long-range functions of the Science Institute with, I think, as a goal deciding whether or not a new building or what size of additional space might be required.

Dr. FIELD. Mr. Chairman, could I just make a simple qualitative point?

Mr. VOLKMER. Yes.

Dr. FIELD. In my view, the intelligent way to approach a problem like this is to first decide by negotiations between the Institute and NASA what the scope of the activities should be, what needs to be done. Of course, it's silly to mandate a scope of activities and then not to permit the manpower to carry them out, so the crucial debate is what activities need to be done and then from that would follow the proper staffing, it seems to me.

Mr. VOLKMER. All right. Would any of that have to do with a possibility as to, instead of having astronomers who are having a program being operated on-board at the Institute—is that absolutely necessary, or is there a possibility that the data can be generated through a proposal and the proposal actually operated by the scientific staff that is there? Do you understand what I'm saying?

Dr. FIELD. I think I do, but I think Dr. Spitzer should——

Mr. VOLKMER. Instead of trying to bring somebody on each time there's a program.

Dr. SPITZER. The difficulty is, we have had extensive experience with guest observers with the Copernicus satellite, and at least at the beginning when observers started to use Copernicus for their own programs, it was really absolutely necessary that they come to Princeton and talk with our own—with the Princeton astronomers, just to understand what is possible with the instrument and what wasn't, and in what form the data emerged and how it should be analyzed. If they just stayed at home and asked for information and waited until it got back, they would ask for stuff that we couldn't get or that wasn't useful. It was really mandatory for——

Mr. VOLKMER. It seems that what we're talking about is communication, then.

Dr. SPITZER. Yes; now after they had had experience of several years, then their visits to Princeton didn't need to be as frequent, or in some cases they just wrote in and said, "Would you please do the same thing for a different star?" I expect that will happen with the space telescope, that the habitues won't need to visit the Science Institute as often as the astronomers that are just beginning to use the instrument, but there is an educational process that is required before one can make effective use of a complex instrument.

Mr. VOLKMER. Well, I think we all, in looking back on the telescope and the cost overruns, what it was supposed to cost and what it has cost us and the effect of that as on the total budget—and this was what basically I'm getting to because—and I am going to defer to the gentleman from Washington in a minute for purposes of a

question. I'm taking a lot of time, but what concerns me a little bit is that as we get into from development to actual operations, that the projected figures for the operations will increase, and then we're going to have also the question of refurbishment and maintenance. If we have a basic, stable type of budget with a very slight increase and most of that increase maybe going—a good part of it going to the space station—what does this do to the rest of the astronomy program in NASA? Do you understand where I'm going?

Dr. SPITZER. Very well.

Mr. VOLKMER. Is the space telescope whole program going to take up most of that, where we can't continue on with the other things that we want—AXAF and UARS and SIRTF—you know, in the future, the things you're talking about, the more advanced and larger telescopes? That's the thing that concerns me.

Dr. SPITZER. A very legitimate concern, and I think it requires a full discussion of just what one gives up when one does cut the budget, and how this compares with other uses of the funds.

Mr. VOLKMER. The gentleman from Washington.

Mr. CHANDLER. Thank you, Mr. Chairman. I don't mind at all yielding time that I might otherwise take to you and your questions.

The question that I have is somewhat related to that. Congressman Brown may have addressed this, but in the Woods Hole report the suggestion is made that in order to make the best use of scarce and valuable observing time, the astronomical community should be involved through the Institute in the evaluation of experiments and the allocation of time on the telescope. Dr. Field, you addressed this in your comments, and then you suggested that a working group of astronomers which includes five different groups—planetary astronomy, stars and star clusters in our galaxy, galaxies and clusters of galaxies, interstellar and intergalactic matter, and quasars and active galactic nucleii—would all be represented. I don't have a very good understanding of what each of those groups represent, as a layman, but I would guess that in terms of distance from Earth they represent quite a span.

Dr. FIELD. Right.

Mr. CHANDLER. I am concerned, I think, that we make good decisions on the use of this telescope, especially given the resources being devoted to it, and I am concerned that we not put ourselves in the political position of having to satisfy people who might otherwise pursue their—as you put it—key projects, simply because they are part of a working group. I would assure the Congress that we're not simply giving everybody their little slice to keep them quiet, but that we really are going to come up with key projects that can best be served by the space telescope and that some people may well go away mad, and come here and complain. Well, so be it, as far as I am concerned, but I would like to hear an assurance that you are going to use the best judgment and the best use of the time of that telescope.

If I have duplicated your question, Mr. Brown, I apologize.

Dr. FIELD. I believe it is a different question, Mr. Chandler, and I would like to address it. I believe that the philosophy, as I explained it in my presentation, is precisely that the proposals which are successful should be those which are of highest scientific merit,

from whatever subdiscipline of astronomy they may come. The reason that we are contemplating a division of some of the activities of this review committee—the Telescope Allocation Committee or the Time Allocation Committee—into various subdisciplines is not a political one but a scientific one, stemming from the fact that it has already been verified that there will be large numbers of proposals in each of these subdisciplines. Therefore, there have to be experts to evaluate them. That would be the first step of the process.

Now I think the point that you are making is perhaps relevant to the second step of the process, where the Telescope Allocation Committee sits as a body to compare the proposals of high merit in category 1 with those in category 2. It is anticipated that this is going to be a difficult problem because there will be a tendency, in all honesty, for each subdiscipline to claim a certain fraction of the observing time. It will take great effort and determination to not yield to that pressure. That is the current thinking of our committee, that the Time Allocation Committee should not yield to that pressure; that it should interleave the proposals from the various disciplines on the basis of overall scientific merit, judged as best as can be done by the chairs of these subdiscipline panels plus some outside members.

Mr. CHANDLER. This has already been discussed within the committee?

Dr. FIELD. Yes; within the committee which I represent, it has been discussed and it is recognized as a problem.

Mr. CHANDLER. Thank you for your answer.

Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you.

I now recognize the gentleman from New Mexico.

Mr. LUJAN. Thank you, Mr. Chairman.

I think that's excellent, because I sit on the other subcommittee engaged primarily in nuclear research, and in the Fusion Program one of the things that has happened is that the big machine boys have gotten control of the apparatus in the Department of Energy, and the guys that think that it ought to be done with small machines are just kind of on the outside looking in, so I think that the review process is a very, very good one.

It is interesting that you said, Dr. Field, that in consultation with NASA we should set the parameters within which we will work and from that establish a budget. That's a little different than we normally hear. As a matter of fact, I just came back from a meeting with President Duarte of El Salvador, and he was saying, "Give us the money and don't place any conditions on what we are going to do. Let us just decide what we are going to do." So it's kind of refreshing when somebody comes and says, "Let's see what we are going to do first."

But that raises the other question that Dr. Spitzer talked about, and that is, you set your priorities, you set the funding, and assuming that it's level funding, where do we go for the money? Do the other astronomy programs suffer, or do we cut back on the priorities of the telescope?

But anyway, those are just some general comments. I do have one question. Let's assume for the moment—it is my understand-

ing, at least—that compared to the problems that we have had in the past with the space telescope, that things are going along pretty well and that we can look forward to the day when we will have it in orbit and well operating. Assuming that all that goes well, is there any planning going on with the successful mission on Solar Max and with the shuttle being able to repair things, is there planning going on—and let me put it in a very simple way—do we know how long the instruments should last, moving forward from the time when it is in orbit? Is there a planning process going on, how to keep it there and the repairs and those sorts of things? Is there already some action going on there.

Dr. FIELD. I think I should refer that to Dr. Spitzer.

Dr. SPITZER. Yes; well, this is a very active field. The maintenance of the telescope itself I am sure will be discussed extensively by the NASA people when they are here, and I think Bob Bless, who is the next speaker, will say something about the replacement of the instruments. I am somewhat familiar with that, but less so than Bob Bless, so it is——

Mr. LUJAN. But it is moving in that direction?

Dr. SPITZER. Certainly.

Mr. LUJAN. What concerns me is, we were talking some time ago with the National Academy of Sciences, and they were talking about a 5-year plan. In the space business, 5 years is here already. It's just like with the space station and those things. We're not satisfied with a 5-year plan. We set a minimum of 20 years to look into the future, and that's the concern, that it not get way, way out there without the proper planning.

Dr. SPITZER. I believe that the objective of the refurbishment program is that any piece of equipment that is likely to fail in the period of less than 15 years, and that can keep the space telescope from working, should be replaceable.

Mr. LUJAN. But even beyond that, you know, there will be a gradual going down in one form or another, decay——

Dr. FIELD. Deterioration, yes.

Mr. LUJAN. Yes; and it needs to be looked at again, and we have sort of plans to push it up a little bit, not quite to its original level, but things of that type is what I'm talking about.

Dr. SPITZER. I had quite a substantial argument with some of the people at Marshall about the use of tape recorders, which have traditionally failed on the satellites that I have been familiar with. They convinced me that they had so many tape recorders and they had been so improved that the chances of all of them failing in 15 years were negligible. The tape recorders are not included in the items that are to be replaceable.

Mr. LUJAN. Thank you.

Dr. SPITZER. That's a subtle thing that's going on.

Mr. LUJAN. Thank you.

Thank you, Mr. Chairman.

Mr. VOLKMER. George, do you have any further questions?

Mr. BROWN. No.

Mr. VOLKMER. I have a couple more. I am deciding which ones.

In the division of the time that has to be utilized, a certain amount for the Director and certain scientists and investigators, et cetera, guest investigators, and then within that certain groups as

you have mentioned and the gentleman from Washington mentioned, we also have the question of some investigations will be short term and some will be over a longer period of time. You will also take that part into consideration, will you not?

Dr. FIELD. Yes, Mr. Chairman. In particular, the key projects have as one of their defining elements that they will take a substantial amount of time, so that particular type of long project will be addressed under what we call the Key Project Program but, in addition, there may be other projects which are not labeled as key projects which will take a long time. I think our present thinking—although this is not yet defined very well—is that they can compete also under the general observing program, and from time to time there will be meritorious projects put forward by an individual or a group which do take a substantial amount of time and yet have not been labeled as key projects. It is anticipated that they can be carried out, but in truth there is—as you can see, we are trying to deal here with a system in which there will be a very large number of proposals for relatively small amounts of time and a few proposals for larger amounts of time, and trying to accommodate all of them within the very limited time of the space telescope on the basis of scientific merit. That's the goal, at least, that we're trying to do.

Mr. VOLKMER. And yet we're looking at anywhere from 200 to 400 guest observers a year?

Dr. FIELD. I don't know what the numbers will be. Perhaps Dr. Spitzer can give a better estimate than I.

Dr. SPITZER. That's a good range, the number of approved proposals.

Mr. VOLKMER. Right, that's what I'm saying, approved proposals.

Dr. FIELD. Yes.

Mr. VOLKMER. I think it's going to take quite a pretty good—I hope we have a very good administrative staff, from what I'm seeing.

Dr. SPITZER. I would like to make one brief comment, if I may. I think the really important development from this standpoint is that there are a number of committees set up which are considering these problems. There is an orderly way in which the Science Institute is keeping in broad touch with the astronomical community. As regards the specific details of how the time allocation is carried out, I am reasonably confident that after a couple of years of experience, many of these features will be changed. It's really sort of inevitable, but there are channels being set up so that the community will feel consulted and will in fact be consulted, and whatever happens will I think be approved and be wisely done.

Mr. VOLKMER. Even though we've had large ground observatories for a good many years, the operation of the space telescope is going to differ considerably from those operations. Right?

Dr. SPITZER. Yes.

Dr. FIELD. Yes; definitely.

Mr. VOLKMER. We're really charting new ground, then?

Dr. FIELD. Oh, very definitely, except if I may point out, Mr. Chairman, there have been a number of space observatories which Dr. Spitzer mentioned, which have preceded space telescope and

have given a considerable amount of experience in this whole process.

Mr. VOLKMER. The last thing I would like to talk about is that we now have instruments that are going to go up on the space telescope. Do you foresee, during the 15-year operation, any other, new type of instrument that you would like to replace one of those for that are going to be there?

Dr. FIELD. I think from the perspective of the committee that I represent, that issue has not been discussed by our committee, so I should defer to Dr. Spitzer.

Dr. SPITZER. I am a member of a number of committees which have discussed this problem, and we have several candidates for new types of instruments which would certainly be very useful. It's quite likely that when the proposals are actually submitted they will be for instruments that we haven't really thought of, but just two examples of instruments that would be very useful: For one thing, the present spectographs do not really measure the entire spectrum. They were designed rather conservatively and only look at a few hundred elements of the spectrum. It's possible now to design a spectrograph that records much more of the spectrum with one exposure, so you get a lot more data. A new instrument along those lines would be extremely helpful.

Second, the success of the infrared satellite suggests that it would be very appropriate to use the space telescope for certain types of infrared observations. This depends a little bit on what or how the SIRTF plan is developed, but I wouldn't be at all surprised if an infrared instrument were proposed and accepted for installation on the space telescope in the next go around, at least as a possibility.

Mr. VOLKMER. Then along those lines, what about the present instruments and the possibility of future need or need in the future to replace any of those instruments?

Dr. SPITZER. Here again, this is really something which Bob Bless is more familiar with than I am because he is a member of the space telescope working group, but this has been discussed by a number of committees and there are some recommendations that the science working group has made.

Mr. VOLKMER. All right. Would the concept of the Science Institute be useful for other, future observatories such as the AXAF and the SIRTF, STARLAB, or anything like that?

Dr. FIELD. Well, in my opinion, Mr. Chairman, if the Space Telescope Institute is successful in providing a good and fruitful interface between the community and the project, then almost certainly it will be discussed as a possible model for any future projects along this line, but I think it's too early at this point to make a judgment.

Mr. VOLKMER. I have no further questions.

Does the gentleman from California have any additional questions?

Mr. BROWN. No.

Mr. VOLKMER. I want to thank both of you for your testimony here today. It has been very useful and helpful, and I know as far as at least I, and I think you should be addressing too the question of the budgetary constraints that we're all going to look to in the

future and see how those are resolved. We will probably have to talk to you in a couple more years, hopefully when 1986 comes and the telescope is out there. We're going to have to resolve some of these things.

Dr. SPITZER. I think it is a measure of the technical success of the program that our present problems are mainly the ones you just discussed.

Dr. FIELD. Thank you, Mr. Chairman.

Mr. VOLKMER. Thank you very much.

Our next witness is Dr. Bob Bless from the University of Wisconsin.

Dr. Bless, your statement also will be made a part of the record at this point in the record, and you may either summarize or review the statement in full. Following the statement we will proceed with some questions. Dr. Bless.

STATEMENT OF DR. ROBERT C. BLESS, UNIVERSITY OF WISCONSIN, CHAIRMAN, SPACE TELESCOPE OBSERVATORY PERFORMANCE ASSESSMENT TEAM

Dr. BLESS. Thank you, Mr. Chairman.

I welcome the opportunity to describe the status of the ST program as it appears to the members of the space telescope observatory performance assessment team. Since STOPAT is hardly a household acronym, let me just mention that it was formed about a year ago by NASA headquarters to identify technical and design concerns or problems of implementation which could impair the scientific performance of ST. We meet roughly every 3 or 4 weeks.

The outlook for space telescope is much brighter than it was 18 months ago. Many serious problems have been resolved. The program is rapidly moving ahead. Let me quickly review some of the major accomplishments and then turn to the remaining concerns.

After some relatively minor design changes, the latches by which the scientific instruments and the fine guidance sensors are located accurately with respect to the focal plane of the telescope are now in good shape. Modified latches have been successfully tested and nearly all are now installed.

The performance of the guidance system in general and the fine guidance sensors in particular is much improved as the result of several factors. Most important, perhaps, is that Perkin-Elmer has shown that their fine guidance sensor performs even better than they hoped. It now appears that the sensors will be able to acquire and lock onto sufficiently faint guide stars so that space telescope should be able to point to any direction in the sky.

The alignment of the optical elements in the fine guidance sensors had to be made to extremely tight tolerances which have to be maintained during launch, and just recently Perkin-Elmer finished the alignment of a key section of the optics and showed that it had maintained alignment after vibration, which was a significant technical achievement.

Another piece of good news from Perkin-Elmer is that the superb figure of the primary mirror was not compromised after the mirror was integrated in its cell and the three axial and three tangential

restraints installed. In general, Perkin-Elmer has done an impressive job in overcoming past difficulties.

The contamination of the primary mirror has been the subject of a great deal of study and discussion. Clean room techniques have been improved and instrumentation has been constructed which enables the particulate matter on the mirror to be measured at both P-E and Lockheed, and a device has been built with which to clean the mirror. This cleaning method has already been successfully used on the secondary mirror of ST.

Now since the present level of contamination is just barely acceptable, and there is every expectation that even under the best of circumstances it will increase, cleaning the primary mirror is a good thing to do. In addition, elements of the telescope structure to which the mirror is exposed—for example, the main baffle—are being cleaned by several cycles of vacuuming and acoustic noise. Finally, equipment is being constructed to be used in the ST thermal vacuum test which will give some indication, at least, if there is serious contamination of the optics by molecular compounds, which would have their greatest effect on reflectivity in the ultraviolet. It appears to us that everything which is reasonable to do with respect to controlling contamination is in fact being done.

Significant progress has been made with respect to the operation of ST. TRW, with considerable help from the ST Science Institute and the Goddard ST project, has come a long way in developing the science operations ground system. It appears that a workable system will be in place for the launch of ST. However, for various reasons no ground system is ever perfect, and it should not be surprising therefore if some of the top level performance requirements cannot be met at launch.

A continuing effort from now throughout the life of ST should be made to assess proposed changes or modifications in the ground system and weigh their benefits against their costs. In particular, it is important that the launch-ready ground system not compromise ST's ability to meet any of its level 1 requirements in the future.

At the present time, it is our impression that a detailed understanding does not now exist of which level 1 requirements or parts thereof are unlikely to be met at launch—for example, the ability to track moving objects—and which of these could be deferred to some later time. We feel such understanding should be gained soon because only a limited time is left during which modifications to the ground system can be made by launch, if any such were judged necessary.

The scientific instruments have successfully completed a verification acceptance program at Goddard and are now undergoing refurbishment and additional testing. As of mid-May, all of the instruments are on schedule. Thus, the wide-field camera should arrive at Lockheed in early August, with the other instruments following soon after.

The last major prelaunch phase of the ST program is the assembly and verification program at Lockheed which is scheduled to begin this fall. During this time all of the elements of the space telescope will be integrated and finally tested as a whole. It is this phase of the program which STOPAT finds more problematic than any other. The test facilties and the mechanical and electrical sup-

port equipment seem to be in good shape. The test systems software which actually runs a test, however, is not scheduled to be ready until this July. Furthermore, it does not seem to us that the detailed planning for the various tests and their implementation in software is as far along as it should be.

For example, a preliminary integration of the scientific instruments with the spacecraft is scheduled to begin the third week of September. By the established ground rules, all test procedures must be completed in the detail necessary to actually perform the test 1 month earlier, that is, just 3 months from now. In addition, there has not yet been the extensive exchange of information between Lockheed and the instrument people in preparation for such a test which we would hope to see.

Finally, only 6 weeks have been allotted for this preliminary integration, which might be adequate, we feel, only if everything went absolutely perfectly. We are concerned, therefore, that the late start and the marginal test time might result in intense schedule pressure, with the possibility that these tests could be compromised. It would be unfortunate if any of the 85-day contingency built into this 16-month test program had to be used during its very first phase.

Unfortunately, it appears to us that similar remarks could be made about other sections of the Lockheed test program, though with slightly reduced force since they are required somewhat later. We understand that steps are being taken by Lockheed to remedy this situation, and we applaud these efforts. For the moment, however, this aspect of the ST program remains a serious concern to us.

Next let me address the maintenance and refurbishment program by which we all hope that space telescope will remain a productive observatory for many years. Originally, over 100 boxes on ST, including the scientific instruments, were to be replaceable on orbit. For budgetary reasons this number fell to about a dozen but over the last year has increased.

The emphasis so far has been on identifying those critical spacecraft or telescope subsystems with the lowest inherent reliability and scheduling replacement units to be constructed. With one exception, the scientific instruments—though still units which could be replaced on orbit—have not been included in this planning. The exception is an essentially empty box with, however, the proper thermal and mechanical properties so that it could replace any of the four axial instruments should one fail before or after launch. It is simply a plug to fill the gap left by a removed instrument.

One concern our group has is that so far the M & R program has apparently taken the approach of keeping the spacecraft and the telescope operational rather than of maintaining a productive astronomical facility. It is not clear that a broader approach would result in the same strategy as the one currently adopted. No guidelines exist at present. Perhaps NASA should establish level 1 requirements for the M & R program.

In any case, it seems to us that as a beginning, a broader M & R program should at least take into account the following considerations. The scientific instruments should be an integral part of the program. It is generally recognized that of the instruments on ST,

the wide-field camera is quite special in many ways. It is an extremely powerful camera. It provides unique operational support to the other instruments. It will provide the data of greatest interest and excitement to the general public, who have, after all, paid for ST. Finally, of all the instruments it is the only one which would be rebuilt today essentially as it was constructed originally, in large part because of its superb detectors.

For these reasons, the science working group recommended last February that a backup wide-field camera be built. This should be started as soon as possible so as to take full advantage of the availability of key JPL people who built the first wide-field camera. This recommendation is presently being considered by the project.

In addition, the science working group also recommended that the announcement of opportunity for second-generation instruments be released very soon. It may seem strange to do so now, with still more than 2 years to go before launch, but it must be remembered that even with this lead time it is unlikely that a replacement instrument would be ready for flight much sooner than 4 years after launch. In fact, if AO's went out now and every 2½ years thereafter, resulting in two new flight instruments with each AO, one of the original ST instruments would not be replaced until about 9 years after launch. By that time it would be about 15 years old.

Present instruments must be replaced as a unit. Clearly, second generation scientific instruments should be designed so that their box-level subsystems could be replaced on orbit.

Space telescope, which should be operational for the rest of this century, is based on the technology of the 1970's. It may well become advantageous to replace some subsystems with more modern versions rather than with copies of existing hardware. This is certainly true of all of the instruments, the scientific instruments, except the wide-field camera which we discussed above. Imagine still using the technology of the 1950's in today's satellites.

Finally, it has become clear that any maintenance and refurbishment program will be very expensive and, in particular, ground return and repair may well be prohibitively costly. Consequently, alternative refurbishment modes should be actively considered, for example, doing major repairs with ST docked at the space station.

We feel that these and other considerations might well lead to a more productive observatory and a cost-effective maintenance and refurbishment program.

[The prepared statement of Dr. Bless follows:]

Statement of Robert C. Bless, Chairman
Space Telescope Observatory Performance Assessment Team
before the
Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

Thank you for this opportunity to describe to you the present status of the Space Telescope program as it appears to the Space Telescope Observatory Performance Assessment Team.

The outlook for Space Telescope is much brighter than it was 18 months ago. Many serious problems have been resolved and the program is rapidly moving ahead. Let me quickly review some of the major accomplishments.

After some relatively minor design changes, the latches by which the Scientific Instruments and the Fine Guidance Sensors are located accurately with respect to the focal plane of the telescope, are now in good shape. Modified latches have been successfully tested and nearly all are now installed.

The performance of the Guidance System in general and the Fine Guidance Sensors in particular is much improved as a result of several factors, including modifications made to the gyros which greatly improved their noise characteristics and changes in the Fine Guidance Electronics. Most important, perhaps, is that Perkin-Elmer has shown that their Fine Guidance Sensor performs even better than they had hoped. It now appears that the sensors will be able to acquire and lock onto sufficiently faint guide stars so that Space Telescope should be able to point to any direction in the sky, including the galactic poles which are relatively sparsely populated by stars. The alignment of the optical elements in the Fine Guidance Sensors has to be made to extremely tight tolerances which must be maintained during the stresses of launch. Just recently, Perkin-Elmer finished the alignment of a key section of the optics of the second FGS unit (which is the first flight unit) and showed that it had maintained alignment after vibration.

Another piece of good news from Perkin-Elmer is that the superb figure of the primary mirror was not compromised after the mirror was integrated in its cell and the three axial and three tangential restraints installed. In particular, the mirror showed no stresses associated with the mounting points. Perkin-Elmer has done an impressive job in overcoming past difficulties.

The contamination of the primary mirror has been the subject of a great deal of study and discussion. Clean room techniques have been improved, instrumentation has been constructed which enables the particulate matter on the mirror to be measured at both P-E and Lockheed, and a device has been built with which to clean the mirror. This cleaning method has already been successfully used on the secondary mirror of ST. Since the present level of contamination is just barely acceptable and there is every

expectation that even under the best of circumstances it will increase, cleaning the primary mirror is a wise move. In addition, elements of the telescope structure to which the mirror is exposed, for example, the main baffle, are being cleaned by several cycles of vacuuming and acoustic noise before being installed into the ST. Finally, equipment is being constructed to be used in the ST thermal-vacuum test (late 1985 at Lockheed) which will give some indication, at least, if there is serious contamination of the optics by molecular compounds (as opposed to particles), which would have their greatest effect on reflectivity in the ultraviolet. It appears that everything which is reasonable to do with respect to controlling contamination is in fact being done.

Significant progress has been made with respect to the operation of Space Telescope. TRW, with considerable help from the ST Science Institute and the Goddard ST project, has come a long way in developing the Science Operations Ground System. It appears that a workable system will be in place for the launch of ST.

By its very nature, however, a ground system is rarely complete before or even after launch. First, its specifications and design must be written early in the program when the overall system may be poorly or incompletely understood; second, flight experience inevitably shows up deficiencies in the ground system. Space Telescope did not escape the first and is most unlikely to escape the second of these difficulties. It should not be surprising, therefore, if some of the top level performance requirements cannot be met at launch. As a consequence of these considerations, a continuing effort - from now throughout the life of ST - should be made to assess proposed changes or modifications in the ground system and weigh their benefits against their costs. In particular, it is important that the launch-ready ground system not compromise ST's ability to meet any of its Level 1 requirements in the future.

At the present time, it is our impression that a detailed understanding does not now exist of which Level 1 requirements, or parts thereof, are unlikely to be met at launch (for example, the ability to track moving objects), and which of these could be deferred to some later time. We feel such understanding should be gained soon because only a limited time is left during which modifications to the ground system can be made by launch, if any such were judged necessary. Other areas of the ground system which would benefit from more precise definition include the ability of the post-observation data handling system to process data quickly, the availability of ST engineering data to assist in the interpretation of science data, and the adequacy of computing power for data analysis.

The Scientific Instruments have successfuly completed the Verification and Acceptance Program at Goddard and are now undergoing refurbishment and additional testing. As of mid-May, all of the instruments are on schedule; thus the Wide Field Camera should arrive at Lockheed in early August with the other

instruments following soon after.

The last major pre-launch phase of the ST program is the Assembly and Verification program at Lockeed which is scheduled to begin this Fall. During this time all of the elements of the Space Telescope will be integrated and finally tested as a whole. It is this phase of the program which STOPAT finds more problematic than any other. The test facilities and the mechanical and electrical support equipment seem to be in good shape. The test system software which actually runs a test, however, is not scheduled to be ready until this July. Furthermore, it does not seem to us that the detailed planning for the various tests and their implementation in software is as far along as it should be.

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Next, let me address the Maintenance and Refurbishment Program by which we all hope that Space Telescope will remain a productive observatory for many years. Originally, over one hundred boxes on ST, including the Scientific Instruments, were to be replaceable on-orbit. For budgetary reasons, this number fell to about one dozen, but over the last year has increased. The emphasis so far has been on identifying those critical spacecraft or telescope subsystems with the lowest inherent reliability and scheduling replacement units to be constructed. With one exception, the Scientific Instruments (though still units which could be replaced on-orbit) have not been included in this planning. The exception is an essentially empty box with, however, the proper thermal and mechanical properties so that it could replace any of the four axial instruments should one fail before or after launch. It is simply a plug to fill the gap left by a removed instrument.

One concern our group has is that so far the M and R program has apparently taken the approach of keeping the spacecraft and telescope operational rather than of maintaining a productive astronomical facility. It is not clear that a broader approach would result in the same strategy as the one currently adopted. No guidelines exist at present; perhaps NASA should establish Level 1 requirements for the M and R program.

In any case, it seems to us that as a beginning a broader M and R program should at least take into account the following considerations. The Scientific Instruments should be an integral part of the program. It is generally recognized that of the instruments on ST the Wide Field Camera is quite special in many ways: it is an extremely powerful camera; it provides unique operational support to the other instruments; it will provide the data of greatest interest and excitement to the general public who have, after all, paid for ST; finally, of all the instruments it is the only one which would be rebuilt today essentially as it was constructed originally, in large part because of its superb detectors. For these reasons, the Science Working Group recommended last February that a back-up Wide Field Camera be built. This should be started as soon as possible so as to take full advantage of the availability of key JPL people who built the first WFC. This recommendation is presently being considered by the Project.

In addition, the SWG also recommended that the Announcement of Opportunity for second generation instruments be released very soon. It may seem strange to do so now with still more than two years to go before launch, but it must be remembered that even with this lead time it is unlikely that a replacement instrument would be ready for flight much sooner than four years after launch. In fact, if AO's went out now and every 2.5 years thereafter, resulting in two new flight instruments with each AO, one of the original ST instruments would not be replaced till about nine years after launch. By that time it would be about 15 years old! Present instruments must be replaced as a unit; clearly second generation SI's should be designed so that their box-level subsystems could be replaced on-orbit.

Space Telescope, which should be operational for the rest of this century, is based on the technology of the 1970's. It may well become advantageous to replace some sub-systems with more modern versions rather than with copies of existing hardware. This is certainly true for all of the instruments except the Wide Field Camera, discussed above. Imagine still using the technology of the 1950's in today's satellites!

Finally, it has become clear that any Maintenance and Refurbishment Program will be very expensive, and in particular ground return and repair may well be prohibitively costly. Consequently, alternative refurbishment modes should be actively considered, for example, doing major repairs with ST docked at the space station.

We feel that these and other such considerations might well lead to a more productive observatory and cost-effective Maintenance and Refurbishment program.

Robert C. Bless received the Ph.D. in astronomy from the University of Michigan in 1958 after which he went to the University of Wisconsin, becoming a Professor of Astronomy in 1969. Since 1959 he has been active in the ultraviolet space astronomy programs of the Department, beginning with a UV photometry project using the X-15, continuing with about a dozen Aerobee sounding rocket flights, the Orbiting Astronomical Observatories A-1 and A-2, and the Phase B Working Group for the Space Telescope. He is presently the Principal Investigator for the High Speed Photometer on ST and chairman of the Space Telescope Observatory Performance Assessment Team.

Mr. VOLKMER. I guess I could begin with the questions that I had before for Dr. Field and Dr. Spitzer, that they said were basically in your purview and you have addressed those in your statement—that is, on replacement and refurbishment and maintenance.

Besides the wide-field camera, that's the only instrument that really you think we ought to be prepared to have a replacement?

Dr. BLESS. That's right, from the point of view of the considerations I mentioned just now.

Mr. VOLKMER. What are we looking at as costs on that?

Dr. BLESS. It is my understanding that if that were to begin today, to take advantage of the JPL people still there, it would cost in the neighborhood of $35 million.

Mr. VOLKMER. Now you also mentioned that if we go into—and you say you are about ready for announcement of opportunities—if we go into new instruments and do two new instruments for each announcement, that it would be 9 years from the time of the launch——

Dr. BLESS. Yes; one instrument, one of the original instruments on space telescope, would have to last at least 9 years before it finally would be replaced with that kind of a schedule.

Mr. VOLKMER. So if anything goes wrong with any one, the spectograph or anything else, within the first 9 years we're up the creek for a long time.

Dr. BLESS. That's right.

Mr. VOLKMER. For use of any type of investigation using that instrument, of course.

Dr. BLESS. That's right.

Mr. VOLKMER. The other instruments could still be used.

Dr. BLESS. That's right.

Mr. VOLKMER. Now we also, do we not—you addressed the problem of refurbishment—is it not envisioned that the refurbishment, the first part should take place within about 5 years of launch, which would be 1991?

Dr. BLESS. That was the original schedule, yes. I'm not sure to what extent people are still considering that particular schedule.

Mr. VOLKMER. In the first place, I don't believe—I think the possibility is fairly remote that we will have a space station in operation to where it could actually do the refurbishment by 1991. We are going to have to face that.

Dr. BLESS. That's right, but we hope that ST might last until the turn of the century, in which case the space station perhaps could be useful in that regard.

Mr. VOLKMER. I agree with that, maybe by 1996 or 1995 or somewhere along in there, but then we're talking about that 9-year frame and not the earlier.

Dr. BLESS. It may well be that if we have some early mortality with the instruments, with one or more of the instruments, that we will probably or might well have to simply take our lumps and operate without them.

Mr. VOLKMER. If something would occur to the wide-field camera, the spectograph or any of the other instruments, is there any possibility of those being repairable on orbit, bringing the telescope back into the shuttle, such as was done with the Solar Max?

Dr. BLESS. That's hard to say. Unfortunately, the present instruments were not designed with that capability in mind. They were designed to be replaced as a unit, so it would depend critically on which element within an instrument failed. If we were lucky, it might be that an electronics box which was easily accessible by simply removing one panel would be the culprit, and in that case it is conceivable that it could be replaced, but in general I think that would be a rather lucky happenstance which we shouldn't count on.

Mr. VOLKMER. I would like to go back to one other thing: If we go ahead, if NASA and the scientific community go ahead and say, "Yes, let's go ahead with an announcement of opportunity," and we start in the timeframe of 1985, when would be the soonest that we could have a new instrument, the earliest?

Dr. BLESS. It is my understanding that NASA headquarters has allowed approximately 6 years from the time the announcement of opportunity goes out until the time that an instrument is ready to be flown.

Mr. VOLKMER. Would that be done on orbit?

Dr. BLESS. It could be replaced on orbit, yes.

Mr. VOLKMER. On orbit, replaced on orbit as a whole.

Dr. BLESS. The instruments are designed with that capability.

Mr. VOLKMER. We have heard the testimony of Dr. Spitzer pertaining to the spectograph and the possible new design so that we would have a broader range. Is that envisioned as a possible new instrument, as a possibility?

Dr. BLESS. Oh, indeed it is. I think that all of the instruments, with the exception of the wide-field camera, if we were starting over could be designed to be more effective instruments. In fact, that in a way complicates some of the maintenance strategy because the question is, Do you replace or try to repair an instrument if it requires major effort and cost, try to repair an instrument which is not anywhere near as good as one could make now, or do you spend the money to build a replacement which would have greater capability than the existing instrument? That kind of consideration, I think, that tradeoff has not yet been done, and I hope it will be.

Mr. VOLKMER. Even though it is not within your purview as being a witness here today—I would like, since you are a scientist within the field and as future investigator—is it possible, do you see any problems from your point of view with the Science Institute in its operation under the proposals to operate and the allocation of time, et cetera?

Dr. BLESS. Well, I have some questions about it and some comments to make. Let me make it clear, though, that I speak——

Mr. VOLKMER. Just as an individual. Now you are speaking as an individual.

Dr. BLESS. My STOPAT hat is off and I am speaking simply as an individual.

Mr. VOLKMER. Right.

Dr. BLESS. As everybody knows, the Science Institute has grown a lot, and I assume that the National Academy Committee will soon determine whether or not these changes have taken the Institute in a direction which is properly supportive of the long-term in-

terests of the Space Telescope Program. Also I hope that in so doing they may more sharply define the Institute's role. It seems a bit fuzzy at the moment, and I think that would be a good thing to do, to decide exactly what its role should be.

There are some considerations I would like to raise which are of more general concern, matters that will have to be taken up downstream, but it seems to me they are worth thinking about for the future because ST is a different kind of scientific instrument. The point is that as long as a scientific satellite had a life expectancy of only a few years, there was not much point in even thinking about major modifications to its ground system, but ST will be operational for many years. Just as it would be shortsighted not to take advantage of new technology for possible use in the M & R Program, so it would be shortsighted to ignore possible operational efficiencies which experience and technology might offer.

With a given operations budget, every position by which the staff could be reduced would mean that roughly one additional major user of ST could be funded. Thus, any measure by which the operations and support staff could be reduced without unduly impairing ST's operational efficiency would be very important.

Let me give a few examples: The International Ultraviolet Explorer, the IUE, has been an extremely productive and well-run observatory from the point of view of its users. Now because of the timing, the IUE experience played no role as far as I know in shaping the ST ground system in general or the Science Institute in particular. Clearly, IUE with its very specialized instrumentation, and the fact that it is in a geosynchronous orbit rather than a near-Earth orbit, is a simpler satellite to operate than will be ST.

Nonetheless, it is not obvious to me that, were we starting over now and had the IUE experience in mind, that the Science Institute in its present form would be the result. So, one thing is that it would seem to me to be appopriate to see if any of this experience could profitably be folded into ST operations and organization over the long haul.

There is another example with perhaps more immediate implications which has already been referred to by Dr. Spitzer, I believe. That is, unlike the users of IUE, the general observers on ST will not have much opportunity to observe in real time, nor is the IUE observing mode likely to be utilized by ST. That is, observers will not be assigned blocks of observing time. Rather, parts of one observing program will be interspersed with others, and it will be impractical for users to be at the Institute when all of their data are being collected by ST, so after one or two trips to familiarize themselves with ST procedures and people, it is quite possible that many users would rarely return to the Institute. Thus, it is not obvious to me that after a time the general observer workload of the Institute will be as large as is presently estimated.

A much more important consideration, however, is that the technology by which computers can communicate with each other and by which large amounts of data can be stored is advancing rapidly. There have been experiments in ground-based observing from remote sites which have been successful, as have similar experiments with IUE. There seems little reason to believe that such arrangements would not be practicable for users of ST. Even real-

time observing could be done remotely, as well as much interactive data reduction, and so forth.

In this context, many of the support functions of the Institute might well change significantly in character in the future. The Science Institute could, in principle, have been located anywhere in the United States. As it turned out, it is near the Goddard Space Flight Center. It would seem to me to be worth careful study to see if any advantage might be taken of this some time in the future. Many more possibilities will undoubtely appear as time goes on, which might lead to a more efficient ground system and even possibly to a smaller operations staff.

Now, since it is a law of nature that no organization voluntarily reduces its size, it is unrealistic to expect the Science Institute to undertake this function. Therefore, NASA, it seems to me, should continually study means by which the entire operations staff and budget could be decreased so that more funds could go to the users for whom ST was built. The importance of this trascends ST since, for better or for worse, the Institute experience may well be applied to other long-lived satellites.

So let me summarize a sort of long-winded answer: During ST's long life, it is quite likely that new technologies and operational methods will be developed which could significantly improve its efficiency. Thus, no part of ST's operations and management should be considered immune from any changes which, in balance, would increase the scientific productivity of the observatory.

Mr. VOLKMER. Dr. Bless, on that I would like to commend you for your statement but Dr. Spitzer, I believe it was, when I was discussing with him the possibilities of the investigator not necessarily being in-house at the time, pointed out that the experience that they had at Princeton in the past was that sometimes it is better to bring them on board, especially initially, so that there is communication and better understanding and everybody understanding what is attempting to do with the program.

Now in your vision of perhaps what could be done in the future with the Institute and with investigators being at the university or wherever and using software, I suppose, to communicate, do you envision the necessity of what Dr. Spitzer has mentioned?

Dr. BLESS. I agree with what Dr. Spitzer said. At the beginning it's absolutely necessary that observers go, become familiar with the practices and procedures, people, and so on. That you have to do.

My point was that after a trip or two of that sort to gain this familiarity, then it may well be possible to or not necessary to visit the Institute as often, and much of the exchange of information, of observing requirements, of communications and so on, could be done by computer or whatever.

Mr. VOLKMER. So we really are not really seeing two different things. We are just seeing an elaboration on it, and it may be viewed through the use of the software back wherever the investigator is.

Dr. BLESS. That's right. The whole gist of what I'm trying to put across is that ST is supposed to be very long-lived, so it behooves us to think of not just our immediate problems, which of course we all are preoccupied with, but to look down the road quite a bit for 5,

10, 15 years ahead of time to see, to try to imagine what changes might occur and how we might make the Institute more efficient in its operations of ST.

Mr. VOLKMER. Just out of curiosity—and I didn't ask the other two this question, and if they want to address it they can do so—anyway, do you envision that after we have the operations of the space telescope for a couple of years and then we're going to have, hopefully, the UARS and AXAF and the SIRTF and perhaps others also up there as a total scheme in the exploration of space and our universe, that the Science Institute itself could be utilized in those also, or would we have to set up a separate one for each one of those?

Dr. BLESS. That question is rather loaded, as I am sure you are aware.

Mr. VOLKMER. No, I'm not aware. I'm just a layman, you know. I'm like the person that just stepped into the barn, and I may have put my foot in something but if I did and if you don't want to address that, just say so.

Dr. BLESS. Oh, no. No, I would agree with what Dr. Field said, that it is too early to judge how well the Institute idea is working, so there we really can't say. I think even if it worked well, there might be a certain reluctance among astronomers in general to have the same organization running several major observatories, several major space observatories. With the best will in the world, it might appear that too much power, too much is being concentrated into one institution, so there might be more or as much of a political problem, a problem of perceptions, as anything else, were that suggested.

Mr. VOLKMER. Dr. Spitzer, you wanted to speak. You take the mike there.

Dr. SPITZER. Could I just make a brief addition to what Dr. Bless has said? I have given some thought to this, and I am speaking now not as chairman of STIC or as an AURA official or in any other capacity, other than as an entirely private individual.

There are advantages, paper advantages, advantages on paper you could point out of combining all these institutes into one—advantages in principle of communication and cost reduction, et cetera, et cetera. My own feeling is strongly against combining all these institutes. I have a prejudice against large organizations devoted to pure science. Some of them are, in fact, very successful but I have the impression that the problems of communication are exacerbated. There are advantages of a pluralistic society in science, as indeed there are in our country, and I would personally hope that if there are other institutes they will be kept separate, they will be scattered around the country, and that they will not all be concentrated in one large, ponderous, possibly unwieldy organization, but that perhaps represents more an expression of personal prejudice than it does of anything else.

Thank you.

Mr. VOLKMER. You addressed the question—to get back to the original here in your statement—the question of the timeframe of the assembly and verification and the question of the 85 days and whether that would be adequate. Do you have an opinion on that,

as to whether that slack time or whatever you want to call it is sufficient?

Dr. BLESS. That's very hard to say. Different organizations have different ways of estimating that number. "Re-test time" is one phrase that's used. As a matter of fact, I don't believe that this whole test program has been looked at very carefully from the point of view of how much time would be necessary and whether the retest factors were reasonable or not. It's also not clear how productive that would be. It's a very difficult thing to set up because you're doing something that's rather new, rather different, so it's hard to make the estimates.

Our concerns on STOPAT are that the preparations do not appear to us to be adequate, and we are very—soon will be beginning this whole 16-month, 18-month program, and this is what concerns us a great deal, so whether—I guess I would say that if our preparations had been adequate we would be happier with the 85 days. As it is now, the suspicion is that perhaps the 85 days will not be sufficient.

Mr. VOLKMER. I know the scientific community and probably everybody else would be disappointed, but what if we had a slippage from, say, 1986 to 1987 because of some problems? It would be better to correct the problems than to put it up there with the unknowns.

Dr. BLESS. Oh, indeed.

Mr. VOLKMER. There isn't anything of any major significance that would possibly occur that we wouldn't be able to possibly find out with the telescope in 1987 that in——

Dr. BLESS. No. The——

Mr. VOLKMER. Well, we are going to miss——

Dr. BLESS [continuing]. Halley's Comet. That was the major, right.

Mr. VOLKMER. Yes.

Dr. BLESS. No; from that point of view I don't know of anything that would be missed.

Mr. VOLKMER. Do you think it would be practical to develop a preventive or scheduled maintenance program? You know, we look at a lot of other projects that we have, our own personal vehicles and everybody else, that if you do certain maintenance that is scheduled along, you know, you may be better off rather than waiting for something to go wrong. Is it possible to develop such a thing for the space telescope, to anticipate problems beforehand?

Dr. BLESS. It seems to me that in a couple of areas it would be possible and perhaps even necessary to do so. I refer in particular to the power systems. If the batteries failed or if the solar arrays failed, the instruments there and all the equipment would get cold, and it is not clear how many could survive the temperatures which might be reached without the active thermal control that now exists. Therefore, one would risk the danger of losing the entire observatory if something happened to the power system, so that would be one thing which I think should be considered, should be studied for preventive maintenance, if you will.

Mr. VOLKMER. Do you have any feeling for any risk associated with the shuttle, revisits back to the space shuttle for types of maintenance or anything?

Dr. BLESS. I have zero experience in this field and really cannot answer that.

Mr. VOLKMER. We had the solar max pickup with the arm, et cetera.

Dr. BLESS. Yes; that worked out well. You are always worried whenever you start fiddling with something, even on the ground, that you may do something bad to it. Apart from this general consideration, I really can't comment.

Mr. VOLKMER. Well, thank you very much, Dr. Bless. I appreciate your being here today, and all three witnesses. We will continue this discussion on Thursday. We will adjourn at this time until 9:30 on Thursday. At that time we will have the people up from NASA and also Dr. Faber to discuss, a continuation on the space telescope. We appreciate, like I said before, your being bere today. Thank you very much.

[Whereupon, at 11:35 a.m., the subcommittee recessed, to reconvene at 9:30 a.m. on Thursday, May 24, 1984, in room 2325, Rayburn House Office Building.]

SPACE TELESCOPE: 1984

THURSDAY, MAY 24, 1984

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, DC.

The subcommittee met, pursuant to call, at 9:30 a.m., in room 2325, Rayburn House Office Building, Hon. Harold L. Volkmer (chairman of the subcommittee) presiding.

Mr. VOLKMER. The Subcommittee on Space Science and Applications will come to order.

Today, the subcommittee will continue our oversight hearings to review the cost schedule requirements of the Hubble Space Telescope Program.

Earlier this week we heard testimony from members of the scientific community on various aspects of the overall program, and the relationship between the observatory and its users.

This morning we will receive testimony from the NASA Headquarters for the two NASA field centers having responsibility for the program.

Later we will hear from Dr. Sandra Faber, who heads the Space Telescope Institute Visiting Committee.

Our first panel with us will be Dr. Burton Edelson, accompanied by Mr. Samuel Keller of NASA Headquarters; Dr. William Lucas, Director of NASA Marshall Flight Center; and Dr. Noel Hinners, Director of NASA Goddard Space Flight Center.

Suppose we start with Dr. Keller, Mr. Keller—or Burt, do you have an opening——

Dr. EDELSON. Yes, Mr. Chairman.

Mr. VOLKMER. Fine.

STATEMENTS OF DR. BURTON I. EDELSON, ASSOCIATE ADMINISTRATOR, OFFICE OF SPACE SCIENCE AND APPLICATIONS, NASA, WASHINGTON, DC, ACCOMPANIED BY SAMUEL W. KELLER, DEPUTY ASSOCIATE ADMINISTRATOR; DR. WILLIAM R. LUCAS, DIRECTOR, GEORGE C. MARSHALL SPACE FLIGHT CENTER, NASA; AND DR. NOEL W. HINNERS, DIRECTOR, GODDARD SPACE FLIGHT CENTER, NASA, GREENBELT, MD

Dr. EDELSON. Thank you. It is, indeed, a pleasure for me to be here again and to be able to express our appreciation for your and your subcommittee's continuous support for the Space Science and Applications Program.

The Hubble Space Telescope is, indeed, the centerpiece of NASA's Science Program. It is the finest, the most complex and

the most powerful optical instrument ever made. It will be operated in space for several decades, serviced by the space shuttle and later by the space station. We believe that the space telescope will push our knowledge of the origin and evolution of the universe into new realms. It will answer many questions now puzzling the world scientific community, and of course, explore new areas.

Because of the great importance of the Space Telescope Program, it remains our highest priority. I am happy to report the goals we laid out for the Space Telescope Program 17 months ago have been fulfilled. We have since been able to get and to keep this program on track, and I am now confident that barring any major circumstances beyond our control, the space telescope will be completed on time, within budget, and capable of meeting its full science objectives.

As you noted, Mr. Chairman, I am accompanied here today by Sam Keller, by Bill Lucas, and by Noel Hinners, and present are also the project manager and many others of our staffs. Without taking up any more of the subcommittee's valuable time, I would like to introduce Sam, who will lead off the detailed discussion of the Space Telescope Program.

Mr. VOLKMER. Sam, before you start, I have got one thing. I would like for the statement of the ranking minority member, the gentleman from New Mexico, Mr. Lujan, to appear right after my opening statement. That is for the record.

And for the following three witnesses that will follow, I would like for the record to just say that your statements will be made a part of the record, and you may either summarize or give them in full, however you so desire.

Mr. Keller?

Mr. KELLER. Mr. Chairman, thank you. With your permission, I will submit the statement for the record, and will summarize it, trying to hit just the salient points. Particularly since we have both Dr. Lucas and Dr. Hinners with us today, who were prepared to go into many of the details, I will try to give you a fairly short overview, and then with them, respond to questions later on.

Let me begin by repeating Dr. Edelson's comments and state that we do consider it a privilege to have this opportunity to appear before this committee and discuss the progress we have made on the space telescope, which I think many or all of us consider probably to be the most important scientific instrument that will ever have been produced.

Let me begin by commenting on our cost performance. At the present time, the cumulative space telescope development cost is slightly under plan. This underrun is largely due to manpower rates experienced on both the optical telescope assembly and the support system module contracts being lower than planned, and current manpower usage on the optical telescope assembly being less than anticipated. Offsetting these reductions in cost is a slight increase in manpower usage for our systems engineering effort. Although current cost is below plan, it is our assessment that total fiscal year 1984 development cost will be on the plan, and that total program development cost will be consistent with the previous Agency commitments at the end of this fiscal year.

Moving now to the optical telescope assembly, the integration effort for this part of the Telescope Program at Perkin-Elmer has made excellent progress in the last 6 months, thanks in large extent to a determined effort on the part of Perkin-Elmer management and the NASA Resident Office at the contractor's plant. I would like specifically to commend that group of people who have moved from Huntsville on very short notice, have been resident now for over a year at Perkin-Elmer, and as much as any group of people working on this program, have contributed to our ability to turn it around. All of the major structural components of the OTA have been manufactured and are now in the process of final assembly and checkout.

The primary mirror assembly has been mated with the focal plane structure and the critical process of installing and aligning the latches that support the science instruments and the fine guidance sensors is nearly complete.

The next important milestone is the cleaning of the primary mirror, which, if we elect to perform that step, can be completed in the June-July timeframe of this summer.

Following that activity, if required, the assembly of the OTA will continue. Planned completion date for this assembly is mid-August. There will then be 6 weeks of electrical check-out, followed by a month of shipping preparations, and we then expect to meet the scheduled ship date to Lockheed in November of this year.

The OTA integration at the present time is about 3 weeks behind schedule, but we have recovery plans in place, and we are optimistic that the November shipping date will be met, although it does remain and will remain a high-risk operation.

Similar remarks can be made about the other critical element of the ST that is being produced by Perkin-Elmer, the fine guidance sensor and its associated optical control system. Last year, there were serious concerns as to whether the sensor would meet its performance specifications. Today, as a result of dynamic tests at Perkin-Elmer, all fundamental concerns with the operability of these sensors has been resolved.

Referring now to the support systems module at Lockheed, on May 1 of this year, we did begin the integration and check-out of the support systems module. This is the first step in the all-out assembly and verification process. And this will be now the chief concern of Lockheed for the next year and a half. As the acceptance and verification process proceeds, hardware from the other associated contractors will be integrated into the ST and similarly tested.

In addition, the integrated space system will, at designated times, be interconnected with the various elements of the ST ground operations system and the NASA communications network to assure that the entire telescope system will operate safely and efficiently and that the requisite scientific data will be returned from orbit. Assuming that the optical telescope assembly will be delivered on time to Lockheed in November, and we believe it will, all-up assembly of the space telescope will begin on December 1, 1984, and should be complete, with the exception of some minor appendages, by the end of January of next year.

The following year will be devoted to a series of functional and environmental tests of increasing complexity, and this then should

result in a space telescope which will be shipped to the Kennedy Space Flight Center in the spring of 1986 and launched in the second half of that year, and our plans are to launch it very early in the second half.

The current situation at Lockheed is not entirely satisfactory. We have had a number of components for the support systems module not completed fully on the date that we had anticipated, although we have begun the environmental testing of the spacecraft system, we will have to remove some of the black boxes, retest, and bring them back later. We think this can be done consistent with our schedules.

All of these factors have posed significant near-term threats to the maintenance of the assembly and verification timeline. The issue has been the subject of extensive discussions between NASA and Lockheed high-level management. Lockheed has taken certain positive steps, both in their technical activities and in management personnel assignments, to rectify the current situation. Some improvements have been noted, more are expected. Therefore, we believe that the long-term prospects for on-time delivery of the space telescope are encouraging.

Moving now to the science instruments, as you will recall, there are five science instruments which are designed to make optimal use of the space telescope, four are developed by the United States, and one by the European Space Agency. The five instruments have recently completed the verification and acceptance program at the Goddard Space Flight Center. This program was completed successfully and, in fact, was somewhat ahead of schedule, and that again, as the activity at Perkin-Elmer, is a real tribute to the people on the Goddard team who worked very long hours, who worked very ingeniously to bring these experiments and the ground test system together and produce a result which we are all very proud of.

Since that time, the scientific instruments have been returned to their development teams and they are in the rework process. We expect that all the instruments, with the exception of the high resolution spectrometer, will be available at Lockheed in time for the integration to proceed, and the late delivery of this one instrument should not have a significant impact on the schedule.

The science development costs are currently below plan. This is the result of a small reduction in manpower usage on several instruments, and a small cost underrun on the science instrument control and data handling computer development activity. However, we anticipate that as some overtime is required during the year, these costs will come out about as planned.

In the ground system development operations, these are physically located in two places: The Goddard Space Flight Center and the Space Telescope Science Institute, which is located on the campus of the Johns Hopkins University in Baltimore.

The hardware for the control center and data capture facility at Goddard have been delivered and accepted. The software is being developed according to a phased approach with releases occurring at planned intervals. Some of the control center software is currently from 1 to 4 weeks behind schedule. However, these particular systems are not on the critical path.

A major hardware/software system which will be located both at the Science Institute and the Science Support Center at Goddard is the Science Operations Ground System, the SOGS software, but I am sure you have heard much about. The software is being developed by TRW for Goddard. The system right now is from 1 to 4 weeks behind schedule. However, the Science Institute, the personnel from TRW and Goddard are jointly involved in a recovery effort, and the system is now progressing on a course to support the scheduled launch.

There are several development activities currently underway at the Science Institute. The most significant are the science data analysis system and the guide star selection system. The guide star selection system software has recently been identified as being 7 months behind schedule. This is primarily due to an underscoping of the job and having inexperienced software managers in the development task at the contractor site. A recovery effort is currently underway and the required products should be ready when needed. The science data acquisition system continues to make satisfactory progress.

The space telescope postlaunch operations funding level, which is one of the issues that you specifically asked us to address, is currently projected to be approximately $50 to $60 million per year in 1985 dollars. This includes all aspects, including the funding to support the research of the space telescope user astronomers.

In the area of maintenance and refurbishment, the telescope has been designed to permit on-orbit maintenance, repair and reboost and to be retrievable by the space transportation system for possible ground maintenance and refurbishment. The recent announcement by the administration to proceed with plans for the development of a space station, together with the high cost associated with the ground maintenance and refurbishment program as originally conceived, have led us to rethink our activities in this area.

We are fully committed to providing for the on-orbit repair and maintenance of the observatory. It has long been recognized that the risks and costs associated with a ground return mission are very high. Therefore, in light of the space station development, we are currently in the process of studying options to utilize the space station for major refurbishment of the space telescope.

In light of the recent success that we have had in repairing the Solar Max Mission, we are encouraged that a generic capability for on-orbit maintenance and repair can be formulated. We are proceeding along this course of action and we will keep the committee fully informed as our plans progress.

In the area of program management, the NASA Administrator stated to this committee last year that we have reviewed our management practices as well as our technical approaches to ensure that we adhere to the revised program schedule and total cost.

We have taken many steps at NASA Headquarters and elsewhere within the project, to strengthen the management role. At headquarters, we have established a Space Telescope Development Division under an experienced Director who reports directly to Dr. Edelson and me. Key management changes have also been implemented in other elements of the program. These include the appointment of a new and experienced telescope project manager at

the Marshall Space Flight Center; and optical telescope assembly manager and support staff, which I mentioned, have been resident at Perkin-Elmer for over a year. The addition of a senior deputy project manager for systems engineering; increased engineering staff at Marshall and the strengthened systems engineering activity at Lockheed; the appointment of new experienced managers at Goddard; the detail of support system project management and engineering personnel from Marshall to Lockheed; key changes of senior of senior management personnel at both Perkin-Elmer and Lockheed. In addition, we have strengthened the involvement of the scientific community through the creation of the Space Telescope Observatory performance assessment team, which is chaired by Dr. Robert Bless, who I believe spoke to this committee on Tuesday of this week.

In conclusion, Mr. Chairman, we are proceeding in accordance with our rebaselined plan toward a launch in the second half of 1986. At the present time, we believe we can meet that date and not exceed the projected runout cost estimate of $1.175 billion. We must all recognize that the space telescope is an incredibly complex program, which has created demanding state-of-the-art requirements in many technical areas. We believe that our present plan provides an appropriate mix of schedule realism, while demanding superior performance by both the Government and the contractor organizations.

We are very grateful for the consideration and support provided by this committee during the rebaselining of the space telescope development and operations activities, and over the past year, while we have been trying to maintain our schedules and costs. Mr. Chairman, that completes my statement, and I will be glad to respond to questions either now or after Dr. Lucas and Dr. Hinners, as you desire.

[The prepared statement of Mr. Keller follows:]

Statement of

Samuel W. Keller
Deputy Associate Administrator for
Space Science and Applications

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Before The

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

I consider it a privilege to have the opportunity to appear before this Committee and report to you on the present status of the Hubble Space Telescope. As the Administrator has stated previously, the Hubble Space Telescope is the centerpiece for the NASA program in space science and applications, and we expect that it will prove to be the most important scientific instrument ever flown.

The Hubble Space Telescope consists of five major elements, the Optical Telescope Assembly, the Support Systems Module, the Scientific Instruments, the Ground System Development and Operations, and the Maintenance and Refurbishment element. Before I present the current status for each of these areas, I will review the development cost status for the current year. Cumulative Space Telescope development cost is slightly under plan. This underrun is largely due to manpower rates experienced on both the Optical Telescope Assembly and the Support System Module contracts being lower than planned, and current manpower usage on the Optical Telescope Assembly being less than anticipated. Offsetting these reductions in cost is a slight increase in manpower usage for the System Engineering effort. Although current cost is below plan, it is our assessment that total FY 1984 development cost will be on plan, and that total program development cost will be consistent with previous agency commitments. I will now present the current status for each of the major program elements and pay particular attention to those areas that you requested in your invitation to Dr. Edelson.

Optical Telescope Assembly (OTA)

The OTA integration effort at Perkin-Elmer has made excellent progress in the last six months, thanks in large extent to a determined effort on the part of Perkin-Elmer management and the NASA Resident Office at the contractor's plant. All of the major structural components of the OTA have been manufactured and are in the process of final assembly and checkout. The Primary Mirror Assembly has been mated with the focal plane structure and the critical process of installing and aligning the latches that support the Science Instruments and the Fine Guidance Sensors (FGS) is nearly complete. The next important milestone is the cleaning of the primary mirror, which is scheduled to

occur in June. The techniques to be used in this process have already been successfully demonstrated in the cleaning of the secondary mirror, which took place earlier this year. The high degree of cleanliness attained in this activity gives us high confidence that the primary mirror will be restored to near its original condition. NASA has developed detailed contamination control plans to minimize any chance that the optical elements of the Space Telescope (ST) will become further contaminated as the ST Program proceeds.

Following the cleaning of the Primary Mirror, assembly of the OTA will continue. Main and secondary baffles will be installed, followed by installation of the Secondary Mirror Assembly, which is comprised of the metering truss that separates and supports the primary and secondary mirrors, the secondary mirror itself, and a secondary baffle. This work is scheduled to be completed in July. After alignment of the two mirrors, the engineering model Fine Guidance Sensor/Optical Control System, the aperture cover, and the flight electronics will be integrated into the OTA. The planned completion date for this is mid-August. There will be six weeks of electrical check-out, followed by a month of shipping preparations. The scheduled ship date to Lockheed is November of this year.

While the technical progress on the OTA integration has been gratifying, a number of not unexpected difficulties have had to be surmounted. Meeting the unprecented degree of precision required in the various optical alignments has been difficult, and schedule variations of plus or minus several weeks have been experienced. An example of the difficulties encountered was a crack found in one of the titanium latch fittings which required demounting and non-destructive testing of similar fittings to insure that this was an isolated instance. Currently OTA integration is approximately three weeks behind schedule, but recovery plans are in place and we are optimistic that the November shipping date can be met, although this will remain a high risk operation.

Similar remarks can be made about the other critical element of the ST that is being produced by Perkin-Elmer, the Fine Guidance Sensor and its associated Optical Control System. Last year, there were serious concerns as to whether the sensor would meet its performance specifications. Today, as a result of dynamic tests at Perkin-Elmer, all fundamental concerns with the operability of the sensors have been resolved. The engineering models of the Fine Guidance Sensor and the Optical Control Sensor, which will be installed in the OTA and shipped with it, have been fully tested at the subsystem level and integrated together. All that remains is the integrated testing, which will lead to acceptance testing of the system in July of this year. There is currently no reason to believe that the tests will not be successful.

In spite of the technical problems encountered, Perkin-Elmer is tracking quite satisfactorily against both their cost, and against the manpower plan shown in Figure 1. The small manpower underrun is attributed to several activities not starting as planned. As schedule recovery activities proceed in the months to come, it is expected that these favorable variances will vanish, but barring unforeseen technical difficulties, planned work will be accomplished within the FY84 funding allocation.

Although the delivery of the OTA to Lockheed late this year will be the most significant milestone in the Perkin-Elmer program, a considerable level of effort will continue. Three Fine Guidance Systems will remain to be delivered with the engineering model scheduled to be returned to Perkin-Elmer in 1985 for conversion to flight configuration. In addition, Perkin Elmer will expend considerable effort in support of Assembly and Verification activities at Lockheed and in support of launch and post-launch operations.

Support Systems Module

On May 1 of this year, Lockheed Missiles and Space Company (LMSC) began the integration and checkout of the Support Systems Module. This is the first step in the all out Assembly and Verification process. This process will be the chief concern of Lockheed, and NASA management for the next year and a half. The desired end result will be an integrated, fully-proven space system that will be ready for launch and fully capable of meeting the requirements imposed by the operational teams that will operate the ST on-orbit and the scientific community who will use the data it produces.

Until now, LMSC has been primarily concerned with the manufacture and qualification of the structural hardware and electronic "black boxes" and with the development of the procedures, software, support equipment, and facilities needed to integrate and test the Space Telescope. LMSC has now started to integrate the hardware and to use the tools they have developed to determine if the various subsystems will operate together as intended. As the Acceptance and Verification process proceeds, hardware from the other associate contractors will be integrated into the ST and similarly tested. In addition, the integrated space system will, at designated times, be interconnected with the various elements of the ST ground operations system and the NASA communications network to assure that the entire ST system will operate safely and efficiently and that the requisite scientific data will be returned from orbit.

LMSC began functional testing of the Equipment Section of the Support Systems Module (SSM) on May 1. The SSM is the spacecraft which contains the support structure, mechanisms, and the necessary subsystems (e.g., power, communications, attitude control) for the OTA, Science Instruments, and the Fine Guidance Systems to operate together as a functional science observatory. The Equipment Section functional test will verify the operation of the majority of the electronic "black boxes" and attitude control components, and perhaps most important, of the two main on-board computers. It will also verify the interfaces among these subsystems. This test will also provide the first validation of the automated test equipment and test software that will be used throughout the Acceptance and Verification process. Thus, the timely start-up of this first test, on May 1, 1984, was an important objective.

After the Equipment Section functional test, the Science Instruments will be connected to the Equipment Section and their operation and interfaces will be verified. This is planned to be started during September and will be followed by a stacking operation which will provide a fit and function check of the major structural components of

the SSM. If the OTA has been delivered on time to Lockheed in November, all-up assembly of the ST will begin on December 1, 1984 and should be complete, except for some appendages, by the end of January 1985. The next year will be devoted to a series of functional and environmental tests of increasing complexity and comprehensiveness. The end result will be an observatory that is in all respects ready for launch. It is still our plan that the ST will be shipped to Kennedy Space Flight Center in spring of 1986 and launched in the second half of that year.

When the ST Program was rebaselined last year, a detailed examination was made of the planned schedule for Assembly and Verification, with the objective of reducing the risks involved. As a result of this, four months were added to the time allotted for Assembly and Verification. Additional testing and planned rework periods were inserted to increase our confidence that the schedule could be met. Even with these additions, making the 1986 launch date will require superior work by our contractor team and by NASA management. Barring serious unforeseen technical problems, there is no reason why the ST should not be launched when planned.

As stated previously, Lockheed began the Equipment Section testing on time on May 1 and is proceeding with the planned activities. Meeting this important milestone was a significant step forward. However, the current situation at LMSC is not an entirely satisfactory one. A number of the components in the SSM have not completed the environmental testing needed to qualify them for flight and will have to be removed at a later date for these tests. There have been some delays in the delivery of test software and test support equipment, which must be ready in mid-June if schedule is to be maintained. A scheduled "bake out" of the Equipment Section, necessary to reduce contamination, will be accomplished during an optimum window to be selected for early summer. The 3-4 weeks necessary for this bakeout must be made up through double shifting in order to maintain the September start date for the Equipment Section and Science Instrument functional test discussed earlier. All of these factors pose significant near-term threats to the maintenance of the Assembly and Verification timeline. This issue has been the subject of extensive discussions between NASA and LMSC high level management. LMSC has taken positive steps, both in their technical activities and in management personnel assignments, to rectify the current situation. Some improvements have been noted, and more are expected. Therefore, we believe that the long-term prospects for on-time delivery of the ST are encouraging. However, this will be a matter of continuing management concern and attention.

Although schedule trends at LMSC are a matter of concern, they have not yet been reflected in cost which is currently under plan. This is primarily attributed to manpower rates experienced being slightly below plan, a delay in billings from several subcontractors, and a reduction in the amount of fee received by LMSC. However, this favorable cost picture is somewhat misleading. In order to remain within FY 1984 available funding levels, LMSC has delayed some non-critical structural work by several months and agreed to a deferral of 1984 fee. Even with these actions, it will take vigorous management attention to remain within plan for the remainder of the fiscal year.

The contractor manpower usage on the Support System Module shown in Figure 2 is a total of 48 man months above plan. This additional manpower has been required due to difficulties encountered with electronic black box fabrication, electrical ground support equipment development, and support system module test procedure development. LMSC manpower may remain slightly above plan for the remainder of the fiscal year. However, in order to remain within our funding constraints, maintaining the downward trend shown in figure 2 for LMSC manpower will be essential. Plans are in place to accomplish this.

In summary, we believe we have a sound plan for accomplishing what must be done over the next two years to assemble, verify, and launch the ST on time, with the requisite performance. LMSC performance so far against that plan has not totally reflected the experience and expertise that LMSC has clearly demonstrated in the past. NASA has challenged Lockheed to live up to their reputation. We believe they will do so.

Science Instruments

There are five science instruments which are designed to make optimal use of the Space Telescope, four developed by the United States and one by the European Space Agency. The five scientific instruments have recently completed the Verification and Acceptance Program (VAP) at the Goddard Space Flight Center (GSFC). The VAP program was completed successfully and on schedule, which is a great tribute to the people at GSFC who managed this portion of the program. The scientific instruments have since been returned to the development teams for rework. The rework on two of the instruments, namely the Faint Object Camera and the High Speed Photometer, will take place at the GSFC while the others have been sent back to the manufacturers.

The rework schedule which was developed this winter, is baselined and calls for the Science Instruments to be delivered and Ready for Use (RFU) at LMSC on a staggered schedule starting in August. The Wide Field/Planetary Camera (WF/PC) is the first instrument scheduled for delivery to LMSC, to be followed by the Faint Object Camera (FOC), the High Speed Photometer (HSP), the Faint Object Spectrograph (FOS), and finally the High Resolution Spectrograph (HRS) which is scheduled to be RFU in early November.

The rework for the WF/PC is being accomplished at the Jet Propulsion Laboratory (JPL) and includes the installation of a new aperture mechanism, a new filter, and a complete retest. The FOC rework started on April 30, 1984 at the GSFC. The FOC and the HSP are sharing the use of the thermal-vacuum chamber at GSFC to avoid shipment of the FOC back to the European Space Research and Technology Centre in the Netherlands. The FOC rework includes a capacitor and science data memory replacement and retest as well as an ultraviolet calibration. The HSP was built by the University of Wisconsin. The HSP rework includes installation of filters, replacements of the Power Converter and Distribution System, internal maintenance and cleaning, as well as retesting.

The FOS was built by the Martin Marietta Corp. for the University of California - San Diego. The FOS instrument has experienced detector

problems. The red detector has been rebuilt and will be installed in the instrument shortly. Recent tests on the blue detector have indicated that it is flightworthy and it has been reinstalled in the FOS. A high ion count during pre-vibration testing on the rebuilt red detector is being monitored. If the high ion count which implies the potential for a drop in quantum efficiency increases, the red digicon will have to be replaced. This would create the need for the installation of a new detector in 1985. The HRS requires a changeout of both detectors, replacing the baffle, realigning the detector mirror, and other work, including complete retest and calibration. The schedule time available for HRS refurbishment is extremely tight. At this time, all instrument rework activities are on or ahead of schedule.

It is currently expected that all of the instruments, with the exception of the HRS, will be available for the Support Systems Module-Equipment Section and Science Instrument interface testing which, as noted earlier, is scheduled to begin during September 1984. This interface test does not require all of the instruments to be available at the start for all of the objectives of the test to be met. The impact of not having the HRS available for the test is that correcting problems discovered in the HRS during further testing at LMSC will be more difficult, but is not judged to represent a threat to the overall ST schedule.

Science development costs are currently below plan. This is the result of a small reduction in manpower usage on several scientific instruments, and a small cost underrun on the Science Instrument Control and Data Handling computer development activity. However, we anticipate total FY 1984 cost to be close to plan.

Ground System Development and Operations

This program element encompasses the development and operations of the total ground system which will enable the operation of the observatory and the conduct of astronomy observations, and it provides support for research by the scientific community. The ground system will be physically located at two principal locations: the Goddard Space Flight Center (GSFC) and the Space Telescope Science Institute (STScI) at the John Hopkins University in Baltimore. The facility at GSFC includes the Payload Operations Control Center (POCC), which was recently formally dedicated and occupied, the Data Capture Facility, and the Science Support Center. The Science Support Center, which is operated by the STScI, is the facility for the daily scheduling of science observations, and the site for control of real-time interactive observations.

The hardware for the Control Center and Data Capture Facility have been delivered and accepted. The software is being developed according to a phased approach with releases occurring at planned intervals. Some of the Control Center software is currently from one to four weeks behind schedule. However, these systems are not on the critical path and the schedule slips will not impact the overall test requirements. The Data Capture Facility is proceeding towards a completion date of September 30, 1984.

A major hardware/software system which will be located both at the STScI and at the Science Support Center at GSFC is the Science Operations Ground System (SOGS). The SOGS, which is being developed by TRW for GSFC, consists of four major subsystems: the System Software; the Observation Support System; the Post Observation Data Processing System; and the Science Planning and Scheduling System (SPSS). Each of these subsystems is from one to four weeks behind schedule. The SPSS is currently on the critical path and has recently completed an extensive recovery effort. The primary reason for the recovery effort was that the definition of and agreement to the requirements for this system were determined to be insufficient, were upgraded in 1983, and hence were developed later than desired. The STScI, TRW and GSFC were jointly involved in the recovery effort and the system is now progressing on a course to support the scheduled launch. The schedule for SPSS is very tight but attainable.

An enhancement phase of the Science Operations Ground System is being studied. This may result in a mechanism to augment the SOGS system at some later date, possibly after launch. A number of study efforts are being conducted to define these requirements. They include a moving target observations study, an end-to-end engineering data study, a data archive and distribution service study and a mission management study.

There are several development activities currently underway at the STScI. The most significant are the Science Data Analysis System (SDAS) and the Guide Star Selection System (GSSS). The GSSS software has recently been identified by the contractor, the personnel of the STScI, as being seven months behind schedule. This is primarily due to underscoping the job and having inexperienced software managers and ineffective management of the development task at the contractor site. A recovery effort is currently underway and the required products should be ready when needed. The SDAS continues to make satisfactory progress.

The Space Telescope Science Institute was established by NASA to plan and manage the ST science program. As the requirements for the operations of the ST have evolved and become better known, so too have the requirements of the STScI. We are concerned about the projected continued growth of the STScI. We are fully committed to an operational ST which optimizes the science return of the observatory. However, this optimization process must consider the budgetary constraints imposed by our commitment to support and start other Space Science and Applications programs. In this light, we have recently commissioned the Space Science Board of the National Academy of Sciences to assist us in re-evaluating the size and scope of the STScI. In the meantime, we are proceeding to complete the development phase of the program as well as prepare for the operations phase.

Current operations costs are slightly under plan. This underrun results primarily from not requiring as much assistance from several contractors as anticipated. Although current costs are below plan, we expect cumulative FY 1984 costs to be close to plan.

The Space Telescope post-launch operations funding level is currently projected to be approximately $50-60 million per year in FY 1985 dollars. This includes all aspects, including the funding to support

the research of the ST user astronomers. It should be noted that these figures will be refined as a result of the various ongoing study efforts which were mentioned earlier. However, we do not expect the figures to change to a substantial degree.

Maintenance and Refurbishment

The Space Telescope has been designed to permit on-orbit maintenance and repair, reboost, and to be retrievable by the Space Transportation System for possible ground maintenance and refurbishment. The recent announcement by the Administration to proceed with plans for the development of a Space Station, together with the high cost associated with the ground maintenance and refurbishment program as originally conceived, have led us to rethink our activities in this area.

We are fully committed to providing for the on-orbit repair and maintenance of the observatory. It has long been recognized that the risks and costs associated with a ground return mission are very high. Therefore, in light of the Space Station development we are currently in the process of studying options to utilize the Space Station for major refurbishment of the ST. In light of the recent success that we have had in repairing the Solar Maximum Mission spacecraft, we are encouraged that a generic capability for on-orbit maintenance and repair can be formulated. We are proceeding along this course of action and we will keep the committee fully informed as our plans progress.

At the same time, we are proceeding with the development of the Space Support Equipment which will be used to support on-orbit repair, and we are continuing with the procurement and development of subsystem spares and orbital replacement units. A preliminary design review of the Space Support Equipment is scheduled for September 1984.

We intend to issue an Announcement of Opportunity for the second generation ST instruments in July. We are allowing for the procurement and development of two instruments (which may be two axial, or one axial and one radial) to be available in the 1990-1991 time period. In addition, we are consistently updating our reliability models and risk analyses to support the planning for spare and replacement parts.

Maintenance and Refurbishment costs are currently under plan. These costs have intentionally been held under plan pending the result of space station studies and the resulting implications to changing generic agency capabilities, which should result in cost savings to the Space Telescope program.

Program Management

As the NASA Administrator stated to this committee last year, we have reviewed our management practices as well as our technical approaches to ensure that we adhere to the revised program schedule and total cost. We have taken many steps at NASA Headquarters and elsewhere within the Project to strengthen the management role.

At Headquarters we have established a Space Telescope Development Division under an experienced Director who reports directly to Dr. Edelson and me. This organization is responsible for the direction of all aspects of Space Telescope Development as well as planning for the Space Telescope operations. This latter activity is closely coordinated with the Astrophysics Division. Key management changes have also been implemented in other elements of the program. These include the appointment of a new and experienced ST Project Manager at MSFC and an OTA Manager and support staff which has been resident at Perkin Elmer for over a year; the addition of a senior Deputy Project Manager for Systems Engineering; increased engineering staff at MSFC and a strengthened systems engineering activity at LMSC; the appointment of new, experienced Managers at GSFC; the detail of SSM project management and engineering personnel to LMSC; and key changes to senior management personnel at Perkin Elmer and LMSC. In addition, we have strengthened the involvement of the scientific community through the creation of a Space Telescope Observatory Performance Assessment Team which is chaired by Dr. Robert Bless.

A significant contribution to Space Telescope management has been the development of a program-wide Management Information System. This computer and microprocessor based system will allow a timely collection, analysis, assessment and oversight of program management data. It covers technical tasks as well as cost, manpower and schedule data. The system is not only used to monitor the progress of the Program but also to identify and anticipate problem areas and take corrective action where appropriate.

The Management Information System is currently in use at NASA Headquarters and at other program elements. In the coming months the entire system will be networked together and tied to a central data base. We view this system as a prototype of a Management Information System for all programs in the Office of Space Science and Applications.

Conclusions

In conclusion, we are proceeding in accordance with our rebaselined plan toward a launch in the second half of 1986. At the present time, we believe we can meet that date and not exceed the projected runout cost estimate of $1175 million. We must all recognize that the Space Telescope is an incredibly complex program which has created demanding state-of-the-art requirements in many technical areas. We believe that our present plan provides an appropriate mix of schedule realism, while at the same time demanding superior performance by both the government and the contractor organizations.

We are very grateful for the consideration and support provided by this Committee during the rebaselining of the Space Telescope development and operations activities. We are continuing to consider options for ST maintenance and repair, so that the Space Telescope can be the exciting, versatile tool it was intended to be, but also allow adequate funding for other space science and applications program activities. It is extremely important that we not permit one program, no matter how valuable, to overwhelm our activities to the exclusion of other equally valuable activities.

Mr. Chairman, this concludes my prepared remarks. I would be pleased to respond to any questions you may have.

NASA

OFFICE OF SPACE SCIENCE AND APPLICATIONS

OPTICAL TELESCOPE ASSEMBLY

PERKIN-ELMER CONTRACTOR MANPOWER

FY 1984 APRIL 30, 1984

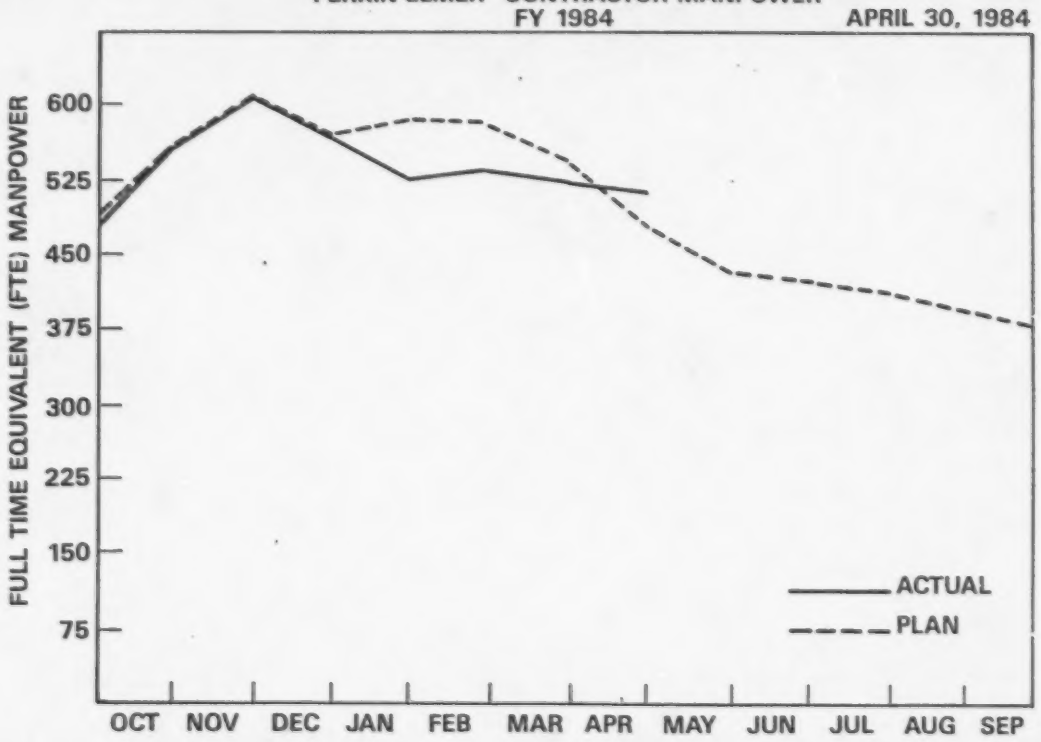


FIGURE 1

NASA

OFFICE OF SPACE SCIENCE AND APPLICATIONS

SUPPORT SYSTEM MODULE

LOCKHEED CONTRACTOR MANPOWER

FY 1984

APRIL 30, 1984

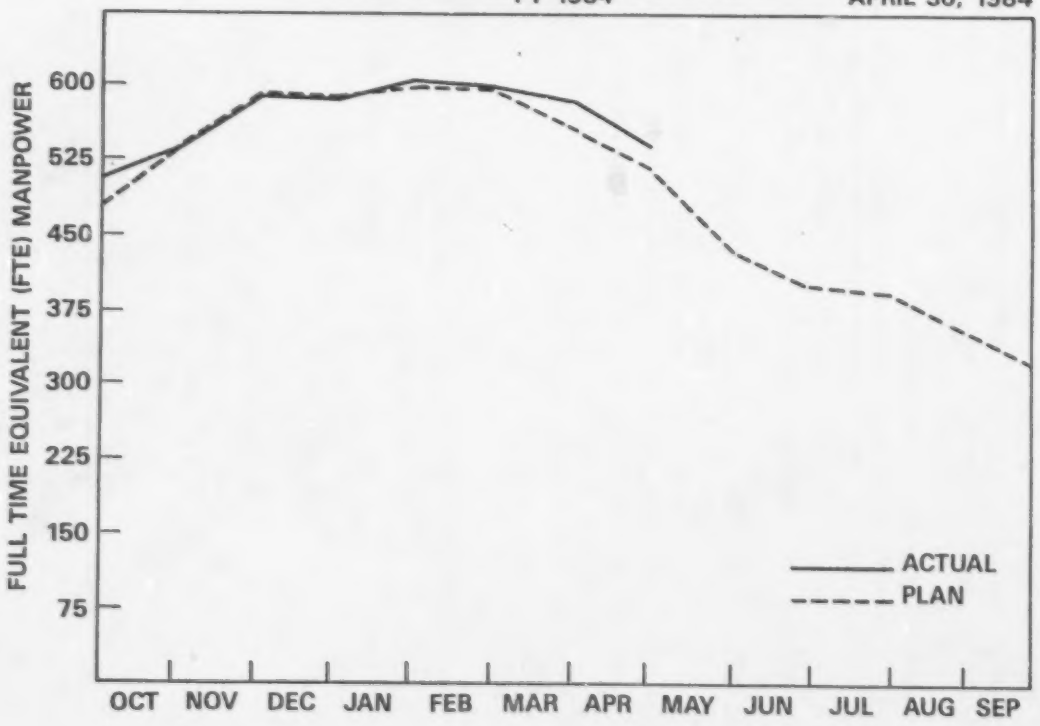


FIGURE 2

Mr. VOLKMER. I think we will wait until we have all of the statements from the other two witnesses, then we will proceed with questions.

At this time, we will proceed with Dr. Lucas.

Dr. LUCAS. Thank you, Mr. Chairman.

It is a pleasure for me to be here today to discuss the status of the Hubble Space Telescope Project. I have a prepared statement that I wish to submit for the record, and with your permission, I will summarize that statement orally.

Before I begin the summary, I would like to present to you Mr. James Odom, who is the project manager at the Marshall Space Flight Center; also Mr. Bill Sneed, my assistant director, who deserves substantial credit for resolving many of the issues that we discussed with you a year ago.

My last report was in June 1983, and today I would like to discuss the progress that we have made since that time, and also indicate to you certain risks that we see still remaining. Just as a reminder, the space telescope system consists of three major systems illustrated on the slide [figure 1] the optical telescope assembly, which is outlined in green; the support systems module, which is in blue; and the five science instruments in beige, that Dr. Hinners will discuss.

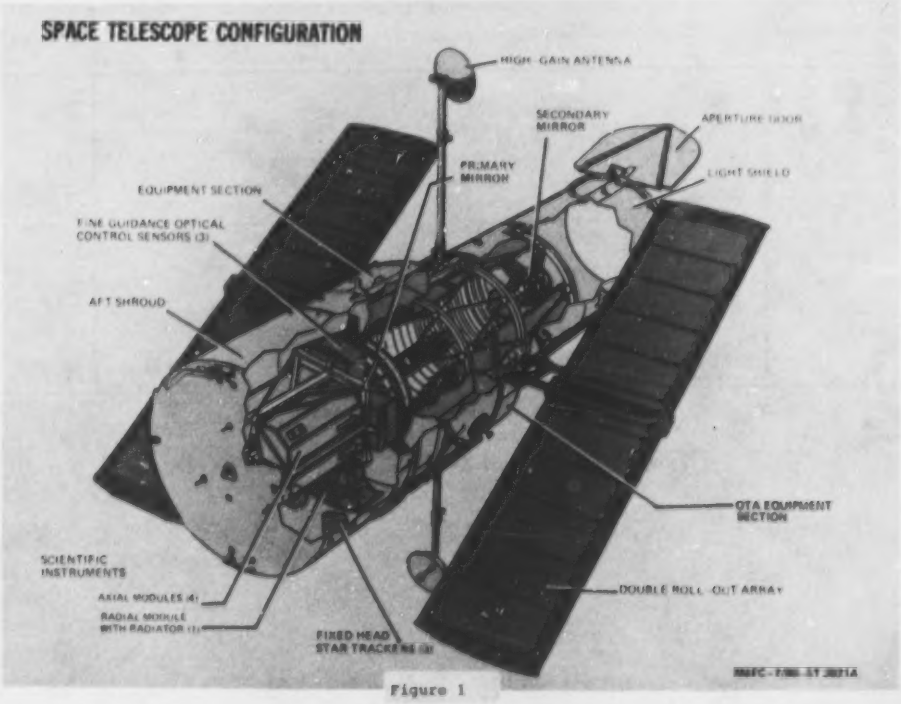


Figure 1

The solar array is constituting a separate unit of the space telescope, and they are being supplied by the European Space Agency.

The space telescope key requirements were discussed and detailed in my June 1983 testimony. Those very stringent requirements resulted in major technological challenges, and were the

basis of some of the concerns that we expressed to you a year ago. I am pleased to be able to report to the subcommittee that the subsystems testing accomplished to date has given satisfactory results. Furthermore, a reaudit by the systems engineering and integration team has discovered no instance where it appears that flight hardware will not meet the established requirements. Thus, I have no reason at this time to believe that all the engineering and scientific requirements will not be fully met.

Overall, the project is progressing according to the schedule established last year, which called for the delivery of the optical telescope assembly by the Perkin-Elmer Corp. to Lockheed in November 1984. This schedule will accommodate the completion of the integration of the science instruments in the telescope, leading to a launch in the second half of 1986. The majority of technical problems and concerns of the optical telescope assembly described to you last June have been resolved; and significant accomplishments have been reported in all phases of the development project.

Now, I would like to just summarize by way of highlighting some of the key accomplishments and the remaining risks.

Excellent progress has been made on fine guidance sensor, a key element of the pointing control system. You will recall that its function is to lock on to faint guide stars and point with extremely high accuracy. In the initial performance verification testing last November, the fine guidance sensor demonstrated capabilities beyond requirements, locking on simulated guide stars as faint as 15.5 stellar magnitude. The manufacturing problems we reported last year concerning the Koesters' prisms, the heart of the fine guidance sensor, have been resolved. Development and manufacturing of the 27 pairs of latches which hold the science instruments and the fine guidance sensors in precise alignment with the focal plane structure, have also progressed well. All of the flight latches have been assembled and delivered, and all except three are qualified.

And these three are well along the way in tests at the Marshall Space Flight Center, and the tests are expected to be completed early in June of this year.

As mentioned in my testimony last year, visible particulate accumulation existed on the primary mirror surface despite very rigorous contamination control measures. At that time, our principal concern was with the large particles, 100 microns and above, and their contribution to scattered light.

On that basis, the primary mirror coverage was estimated to be 0.2 percent, compared to our on-orbit budget allocation of 1 percent. Subsequent analysis of the encircled energy and other scientific requirements revealed that smaller particles, on the order of 10 to 100 microns, should also be included in our consideration. Further, the emphasis shifted from particulate size to aerial coverage. Inclusion of these smaller particles in the analysis raise the estimate of primary mirror particulate coverage from two-tenths percent to 1.4 percent, and the on-orbit budget aerial coverage allocation from 1 percent up to 5 percent.

Although the present accumulation is well within the allowable, we are preparing to clean the mirror to provide additional margin against performance degradation from any more accumulation.

Cleaning methodology has been developed and thoroughly tested and we are prepared to do that process. So far as we know, we have no molecular contamination, that is, molecular film on the mirror. However, we will make measurements during the particulate cleaning to determine if any molecular contamination exists.

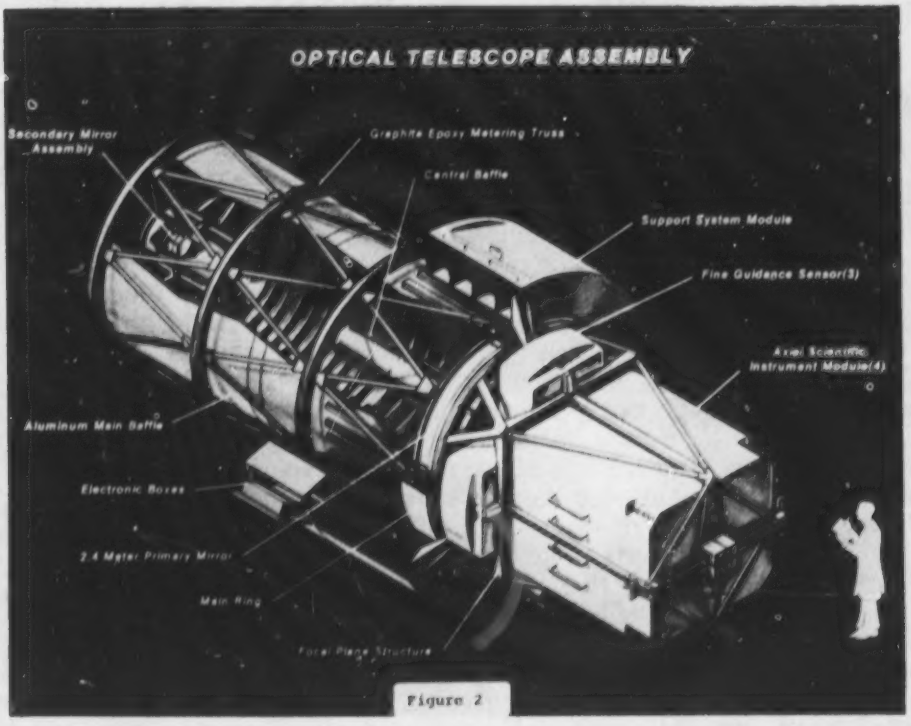


Figure 2

One of the greatest challenges, I believe, to be faced during all the subsequent phases of the space telescope assembly, test, checkout and transportation, is assuring adequate contamination control. A tight-fitting cover shown in the slide [figure 2] there, which doesn't contact the optical surface, currently covers the primary mirror, and it will remain in place, except, of course, during the cleaning operation, until the mirror is integrated into the optical telescope assembly. After that, the optical telescope assembly will provide protection to the mirror. And during the transportation, the entire assembly, and later, the full space telescope will be enclosed in the container that provides environmental and contamination control.

During launch operations, the space telescope will remain covered and it will be just before the shuttle payload bay doors are closed. The engineering model fine guidance sensor has been integrated with the optical control sensor that is undergoing final integrated testing. Figure 3 will show you where this subassembly fits into the telescope, and the next Vu-Graph [figure 4] I show is one of the subassembly tests set up Perkin-Elmer.

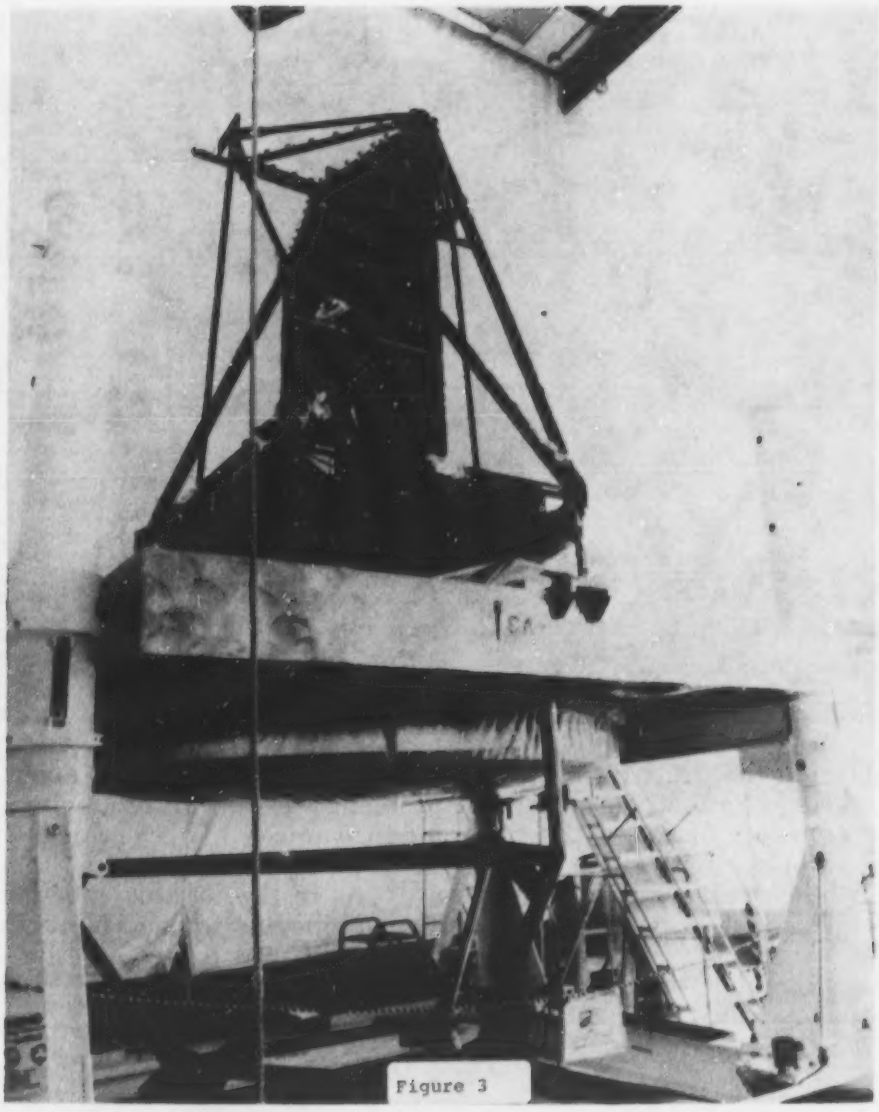


Figure 3

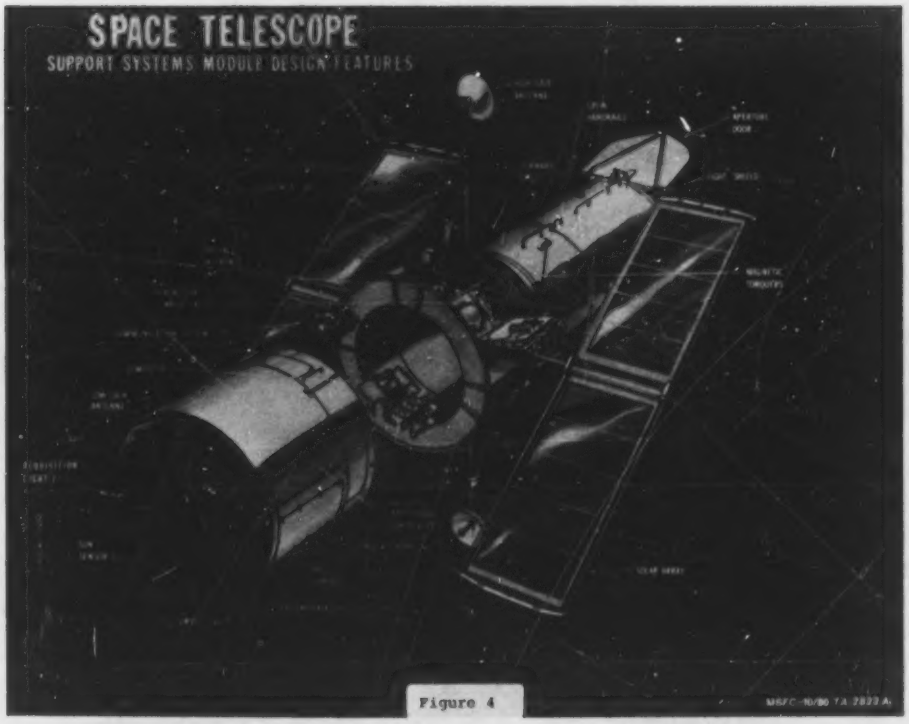
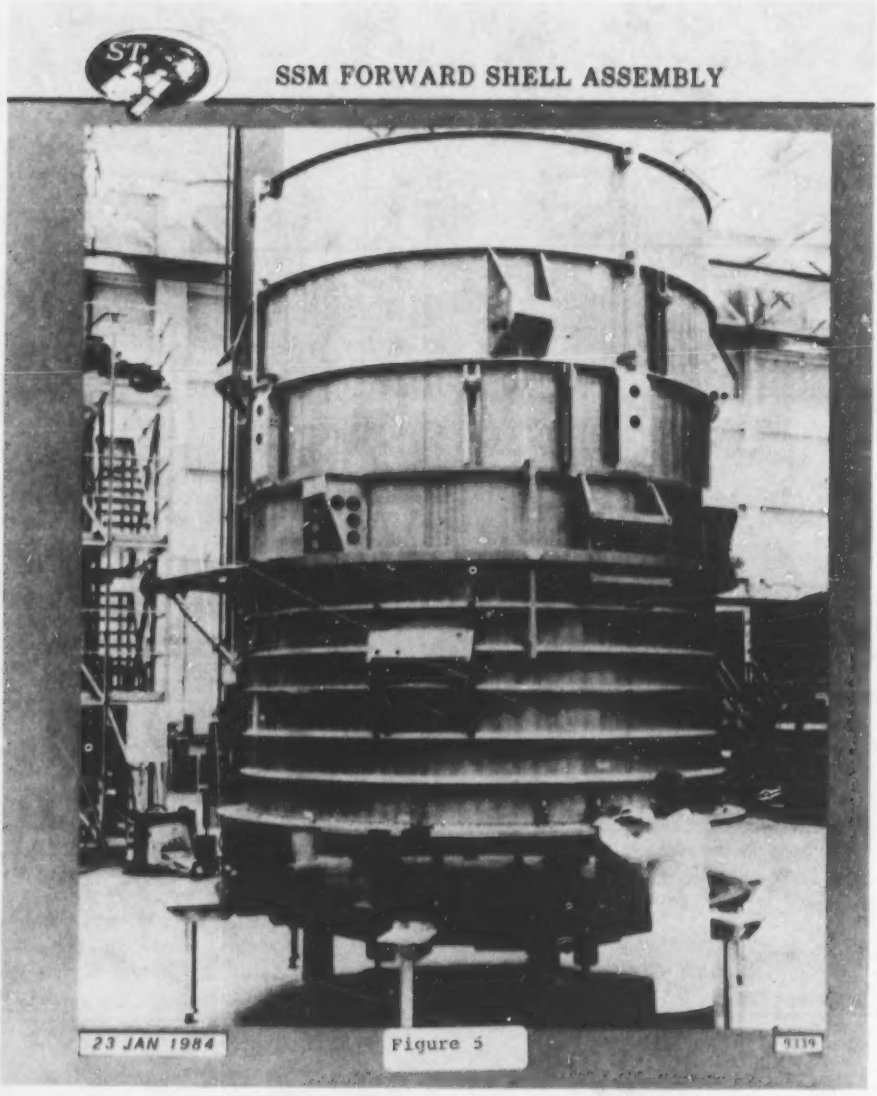
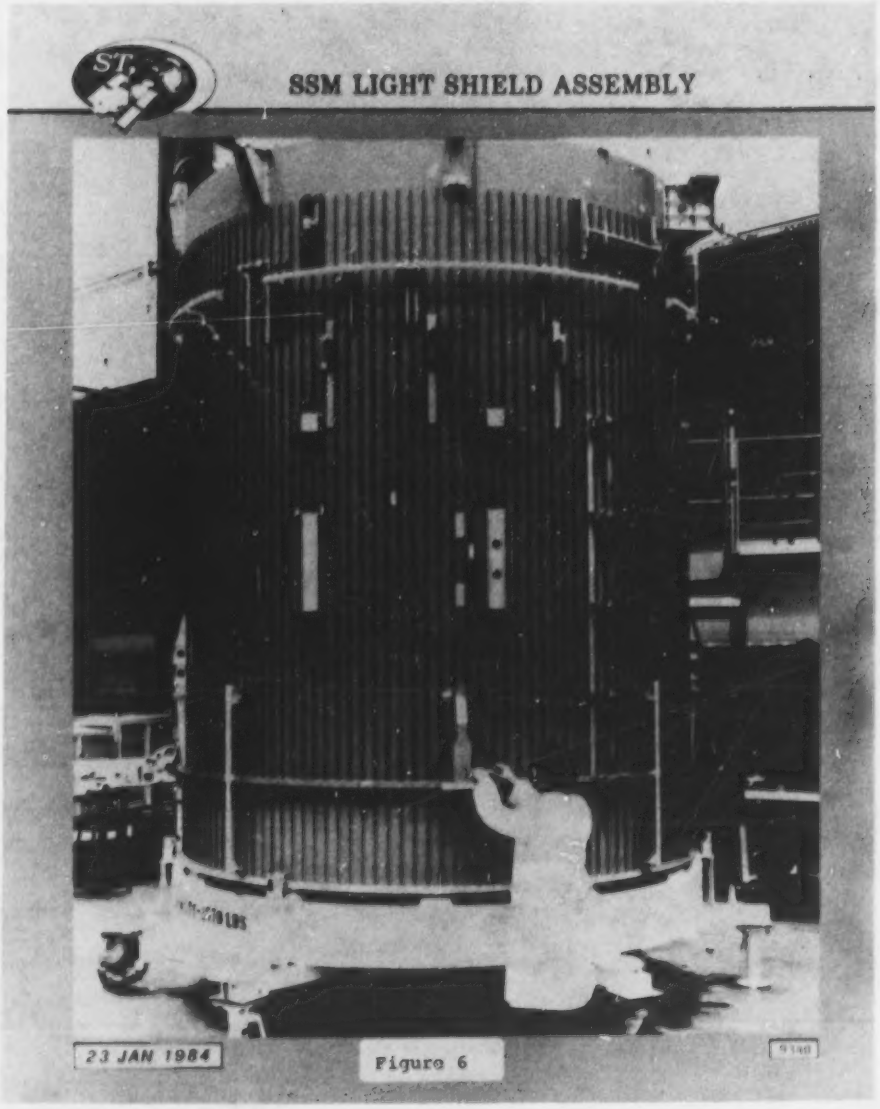


Figure 4

During the preparation for this testing a few weeks ago, about 2 weeks ago, in fact, an alignment problem was encountered with interferometer optics of the fine guidance sensor. This problem did not interfere with the continuation of the dynamics testing, and it will be corrected upon completion of the testing of this subassembly. This should not cause a significant schedule impact. Nevertheless, we must recognize that risks remain until the completion of the alignment and integration testing of the entire optical telescope assembly.



The support systems module, which is illustrated in the next slide [figure 5], provides the basic spacecraft services and the major structural elements that accommodate the assembly of all the systems into the complete spacecraft.



The manufacture and assembly of all the structural elements have proceeded according to schedule. The forward shell and the light shield [figure 6] were successfully integrated and the mechanical interfaces verified. This subassembly encloses the forward end of the optical telescope assembly. Functional testing of the equipment section, which is shown in the next slide [figure 7] is well along the way in its progress.

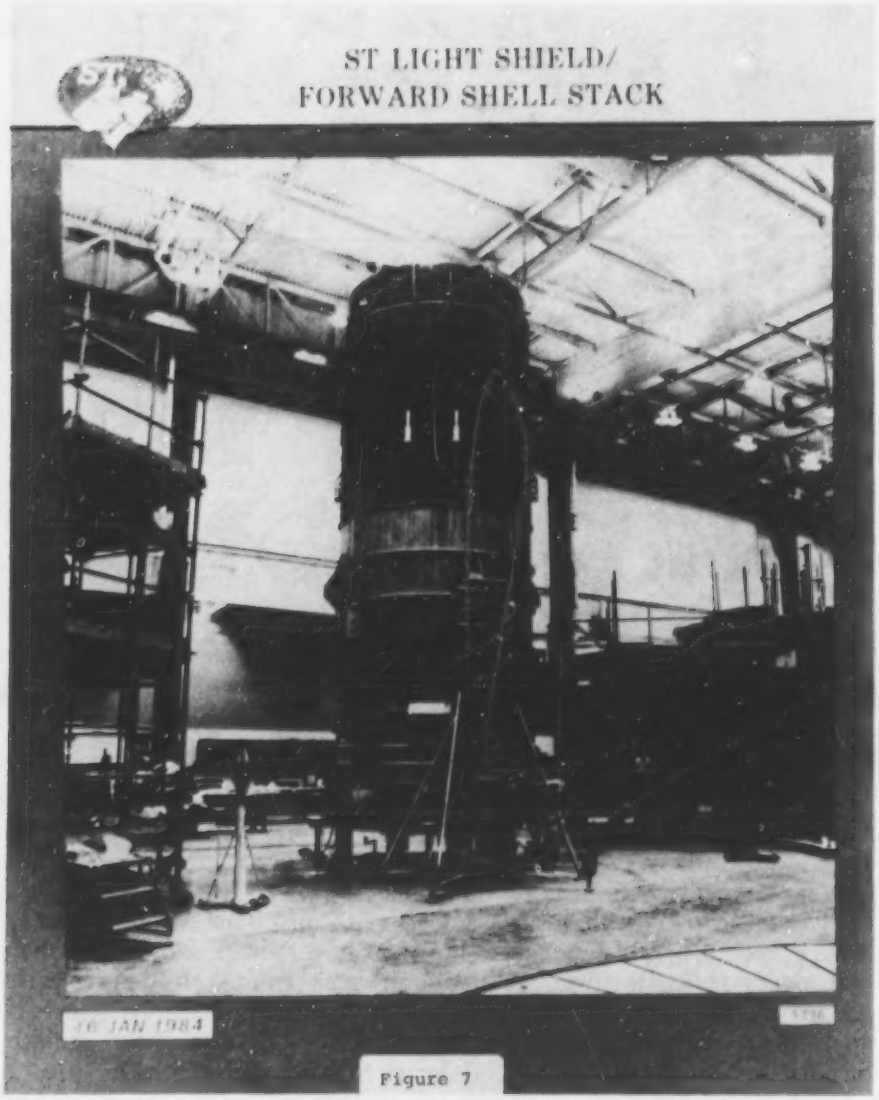


Figure 7

This section contains the support elements, such as the electrical power, the communications, the attitude control that are needed to make the telescope a functioning observatory. And it is attached to the base of the structural subassembly, as shown in the previous slide. The final assembly of the telescope will begin upon the arrival of the optical telescope assembly at Lockheed late this year, and then this will be followed by a series of systems level functional and environmental tests of increasing complexity.

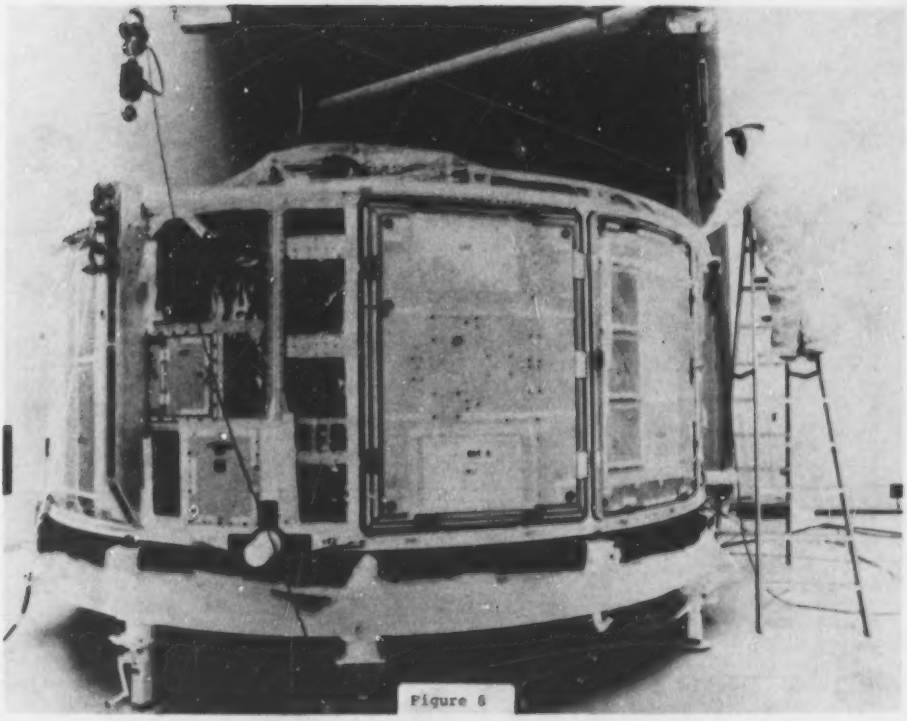


Figure 8

This Vu-Graph [figure 8] shows the interior of the new facility at Lockheed, which was built to support the assembly of the space telescope. The major stands are completed as one can see, and the science instrument receiving and inspection depot, not shown here, but adjacent to this, has been completed.

As reported to you last year, the flight computer memory margin was approximately 12 percent against a self-imposed requirement of 20 percent at launch. A decision was made to use a fourth memory module to correct this situation. And currently, there is a 32-percent margin available for any necessary increases in memory requirements between now and launch, and we consider this adequate.

The manufacture and assembly of the major electronic assemblies are nearing completion. However, these operations have been and continue to be among the most critical schedule elements in the Lockheed effort. This is particularly true of the data management and electrical power systems. The complexity of these assemblies has required more time than anticipated for the the manufacturing and assembly operations, and problems encountered in the checkout phase have required modifications and rework.

Schedule impacts to the downstream assembly verification phase of the support system module would be minimized by utilizing functionally tested but not yet qualified electronic assemblies, and program spares during the assembly and verification phase. Failures have occurred in some of the subsystems of the pointing control systems—some of the components, really. We believe that we

have identified all of the problems that can be identified prior to final assembly, and these are being corrected.

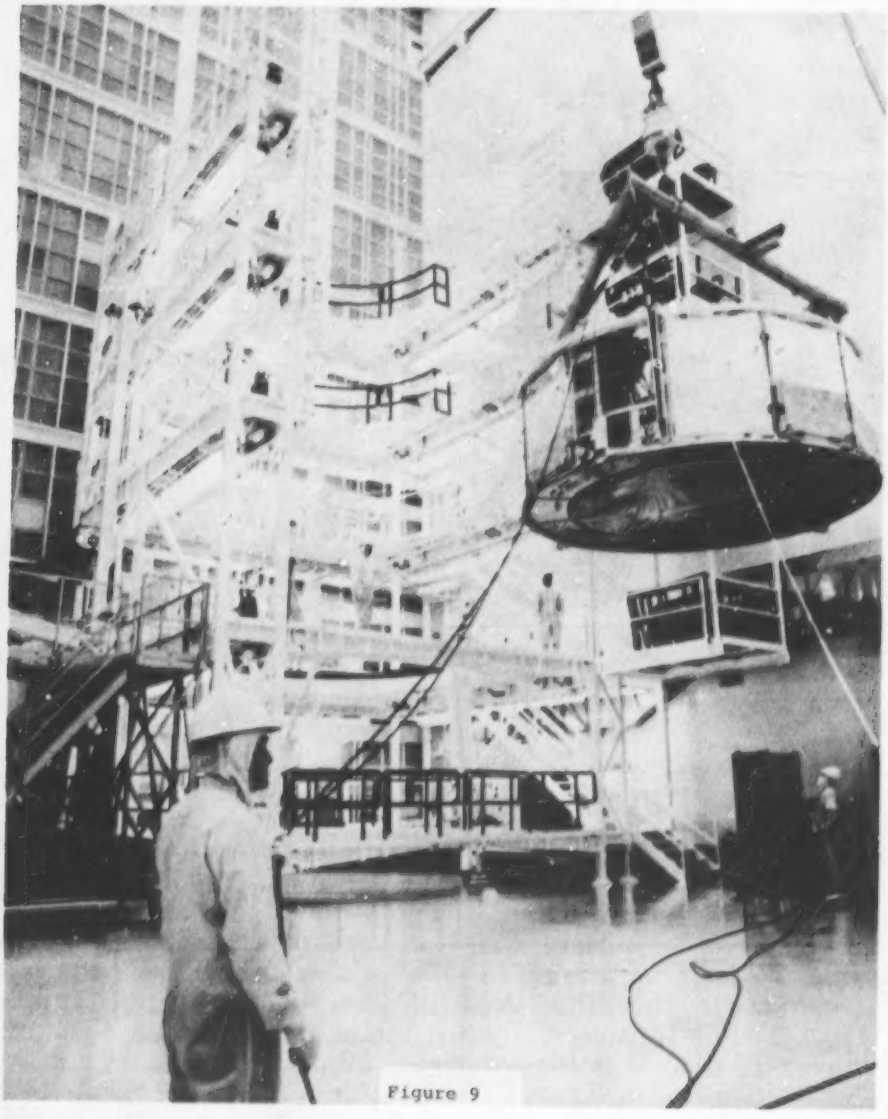
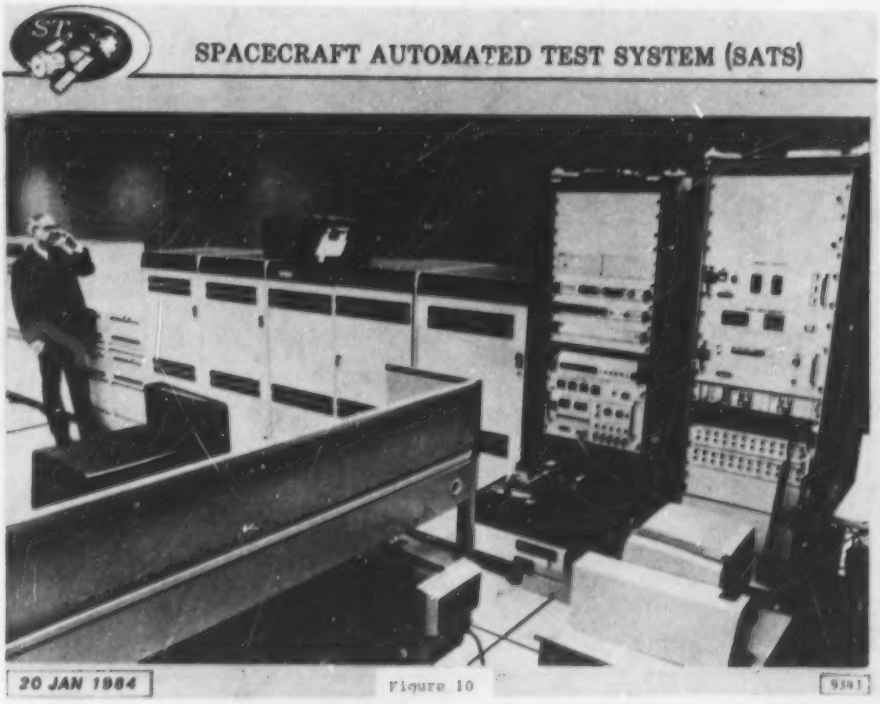


Figure 9



Some schedule delays have been experienced in the installation and checkout of the electrical ground support of the equipment, some of which is shown in this slide [figure 9]. A recovery schedule has been implemented for the automatic test phase of assembly verification, which is scheduled to begin in mid-June. In spite of this recovery plan, there may be a 2- to 3-week threat to the planned start date for this test phase.

The thermal vacuum chamber could not be cleaned within the time schedule to initiate the bake out of the support system module. Work is continuing to prepare this chamber for the bake out; and in the meantime, we will continue the current support systems module testing, and when the chamber is ready, the support systems module will be removed from testing, baked out, and then returned to continue its test program. This could result in an additional 2 to 4 weeks' delay in the start of the integrated testing. However, we believe that selective use of second shift activity will overcome the schedule delay, if, in fact, it materializes.

Mr. VOLKMER. Dr. Lucas.

Dr. LUCAS. Yes, sir?

Mr. VOLKMER. Before you continue, we have got a vote on right now, and I am going to have to leave. We will come back in about 10 minutes, and we will continue on with you.

Dr. LUCAS. All right, sir.

[Recess.]

Mr. VOLKMER. Dr. Lucas, you may proceed.

Dr. LUCAS. Thank you, Mr. Chairman.

Turning now to the assembly and verification test program, this is a very significant and complex phase of the space telescope project. And, the contractors' efforts are being monitored closely to minimize schedule risks.

The science instrument preassembly and verification test was incorporated in the program during the last year to provide early testing, and thus, to reduce risks to the verification testing of the entire assembly. Also, to add to the confidence in the total telescope system, the assembly and verification phase of the program has been modified to allow end-to-end verification of the entire spacecraft and ground operational system.

This verification will include the real-time generation of a precursor observing program at the Science Institute, the transmission of this program to the Goddard Space Flight Center, the generation of spacecraft commands at Goddard, and the transmission of these commands via the tracking and data relay satellite from Goddard to the spacecraft in Sunnyvale. Then data taken from the Hubble space telescope acquired through simulation, will be transmitted back through the same network to the Science Institute.

In summary, the schedule risks resulting from potential difficulties in completing electronic assemblies, the test software and electrical ground support equipment, and contamination control represent the greatest concerns with the Lockheed effort.

Recovery plans have been defined and are being implemented in an effort to maintain assembly and verification schedules. The systems engineering and integration activities are currently focused on the evaluation of the requirements allocated to the various project levels, the performance of interface and design audits, the coordination of a projectwide cleanliness control plan and contamination budget, and the overall coordination and integration of the assembly and verification plans, and in general is making a very important contribution to minimizing schedule risks as we continue with the program.

The solar array system being provided by the European Space Agency is nearing completion, and meets the original power specifications. However, a recent power assistance analysis indicates that the overall systems efficiency will be less than originally planned, and additional power may be required. Accordingly, it has been decided to provide a 10-percent increase in power margin by applying upgraded solar cells to the solar array.

Turning now to the maintenance and refurbishment. The original approach assumed the goal of orbital maintenance each 2½ years, and ground return of the telescope each 5 years. However, maintenance and refurbishment goals are currently under reassessment, as Mr. Keller has just indicated, because it appears that more extensive on-orbit shuttle repair would reduce the maintenance and refurbishment costs significantly below that required for periodic ground return. Furthermore, on-orbit repair has become more attractive with the recent experience on repair of Solar Max and with the potential availability of a space station in orbit at a later time. Therefore, design changes are being made to increase the number of components that can be replaced in orbit. We have significant in-house work at the Marshall Space Flight Center un-

derway at the present for design and development of the space support equipment used for on-orbit refurbishment.

The space telescope management structure discussed with you last year is in place and performing well. The Marshall optical telescope assembly project manager and his staff have continued onsite at the Perkin-Elmer facility, and have provided effective oversight of the activities at that place. The Perkin-Elmer management team has developed a high degree of schedule awareness, and is controlling both its manpower and costs within the cost plan.

The recent schedule performance at Lockheed has been less than desired. Improvement efforts are underway by Lockheed and by Marshall. The Marshall support system module project manager, and a very large portion of his staff have moved to the Lockheed facility earlier than planned, to provide management oversight of the day-to-day contractor operations. Lockheed has initiated some improvements to strengthen its space telescope organization, as well as some of its supporting organizations, but further improvements are required and anticipated.

In conclusion, I would like to stress that substantial progress has been made since my report last June. The project is progressing well and within the estimated runout costs.

The optical telescope assembly is essentially on schedule, and the outlook is good for delivery to Lockheed as planned, in November of this year. While Lockheed has experienced some problems on the support systems module, positive steps have been taken to enhance the capacity to meet project schedules. Although challenges remain as the project continues, particularly through this critical integration and verification phase, sufficient flexibility has been provided to overcome reasonable unforeseen problems.

Intense management attention within the contractor organizations and within the Government is being applied to every facet of the program. All indications are that the space telescope is still on schedule for launch during the second half of 1986. The Marshall Space Flight Center and the entire Hubble space telescope team continue to be committed to the successful completion of the project. Mr. Chairman, that concludes my oral testimony, and I will be happy to respond to questions at the appropriate time.

[The prepared statement of Dr. Lucas follows:]

STATEMENT

of

DR. WILLIAM R. LUCAS
DIRECTOR, MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

for the

SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to appear today to discuss the Hubble Space Telescope Project. The Hubble Space Telescope represents a tremendous advancement in one's capacity to observe the universe, probably the greatest single advancement since the invention of the first telescope. Scientists will be able to see seven times farther into space than with ground-based telescopes, with a resolution 10 times better, and observe objects which are 50 times fainter. To achieve this increased capability necessitates a set of very stringent engineering requirements. These requirements were detailed in my June 14, 1983, statement to your Subcommittee, and I am pleased to report to you at this time that all these requirements are being satisfied. Substantial progress has been made, and reasonable program flexibility remains to give confidence that the commitments made last year will be met.

My testimony today addresses the progress that has been made in the project in the past year in hardware development, systems integration, and planning for mission operations and on-orbit maintenance and refurbishment along with technical and schedule risks remaining in the program. My remarks will be limited to the activities for which the Marshall Space Flight Center has direct responsibility since Mr. Samuel W. Keller and Dr. Noel W. Hinners are also appearing today to discuss certain other elements of the project. To aid our communications, I would like to begin my statement by identifying again the project elements and the management responsibilities.

PROJECT ELEMENTS

The Hubble Space Telescope consists of three major hardware elements, the Optical Telescope Assembly, the Support Systems Module, and five modular science instruments which are the Wide Field/Planetary Camera, the Faint Object Camera, the High Speed Photometer, the High Resolution Spectrograph, and the Faint Object Spectrograph. The Space Telescope configuration is shown on Figure 1. The Solar Arrays constitute a separable element of the Support Systems Module. In addition to these hardware elements, the project also includes the Systems Engineering and Integration, Mission Operations Ground System, and the Science Institute.

MANAGEMENT RESPONSIBILITIES

The Marshall Space Flight Center (MSFC) has the overall project management responsibility for the Hubble Space Telescope. MSFC has direct management responsibility for the Optical Telescope Assembly being developed by Perkin-Elmer Corporation, the Support Systems Module being developed by Lockheed Missiles and Space Company (LMSC), and the Systems Engineering and Integration activities with support from LMSC. MSFC also has management responsibility for orbital verification and maintenance and refurbishment including sustaining engineering.

The Goddard Space Flight Center (GSFC) has responsibility for the management of the Science Instruments, the Science Instruments Command and Data Handling System, the Science Institute located at Johns-Hopkins University, the Ground Systems development and operations, Science Verification and in-flight operations.

The European Space Agency (ESA) is responsible for the development of the Solar Arrays, with the associated drive mechanisms, and the Faint Object Camera. In addition, the European Space Agency is participating in the staffing of the Hubble Space Telescope Science Institute.

DEVELOPMENT

Project Status

The Hubble Space Telescope Project is progressing satisfactorily according to the schedule established last year which called for the delivery of the Optical Telescope Assembly by Perkin-Elmer Corporation to Lockheed Missiles and Space Company in November 1984. This schedule will accommodate the completion of integration with the Science Instruments and Support Systems Module leading to a launch in the second half of 1986. The status and progress of the major elements of the Space Telescope are described in the following paragraphs.

Optical Telescope Assembly

Progress on the Optical Telescope Assembly, illustrated in Figure 2, has been good over the past year. The majority of the technical problems and concerns described to you last June have been resolved, and significant accomplishments have been recorded in all phases of the development process. Figure 3 is a photograph of the primary mirror assembly attached to the focal plane structure.

I am pleased to report that excellent progress has been made on the Fine Guidance Sensor, a key element of the Hubble Space Telescope Pointing Control System, which was reported last June to be one of our most troublesome areas. The decision, reported in my testimony last year, to designate the first complete Fine Guidance Sensor as an engineering model has been proven to be a very sound one. The engineering model underwent initial performance verification testing last November and demonstrated performance capabilities beyond requirements and expectations, achieving near-theoretical performance of the complete optical system and autonomous transition to fine lock, using simulated guidestars as faint as 15.5 stellar magnitude, with good stability and repeatablity. The tests demonstrated that the Fine Guidance Sensor will enable the Pointing Control System to lock onto guidestars with the required accuracy of approximately 0.01

arc second for periods of 24 hours. This resolved previous concerns regarding the basic design of the Fine Guidance Sensor. Problems experienced a year ago with the processing of Koesters' prisms, the heart of the Fine Guidance Sensor, were resolved, and acceptable prisms are now available for all Fine Guidance Sensor units. The engineering model Fine Guidance Sensor has been integrated with the Optical Control Sensor, which was also successfully tested, and is undergoing final integrated testing. Delivery of the three flight Fine Guidance Sensor units will support program need dates, although the units are slightly behind schedule at the current time.

Development and manufacturing of the latches which hold the science instruments and Fine Guidance Sensors in precise alignment to the Focal Plane Structure have also progressed well. All 27 pairs of the flight latches have been assembled and delivered and all except three are qualified. Final dynamic qualification testing of the three Wide Field/Planetary Camera radial latches is currently underway at MSFC.

The majority of the Optical Telescope Assembly special test equipment required to support completion of assembly, alignment and testing activity is in place, and the few remaining items are progressing well within required delivery schedules.

As mentioned in my testimony last year, visible particulate accumulation, very fine dust, does exist on the primary mirror surface despite rigorous contamination control measures. Recent measurements indicate approximately 1.4 percent of the mirror surface is covered with particulate. This figure is greater than the estimate of contamination reported to your Subcommittee last year. The change is due primarily to measuring techniques. However, the results of recent contamination analyses indicate that a revised on-orbit optical surface coverage of 5 percent is now allowable without degradation of optical performance. This is a change from the 1 percent allowable which I quoted in my previous testimony of June 14, 1983, and is derived from a light-scatter study of the effects of the mirror micro-roughness. Even though the present particulate accumulation is well within the established criteria, we are prepared to clean the mirror as a safeguard against performance degradation from any additional accumulation through launch. To clean the mirror, a non-contacting, low risk method of removing particles has been developed and verified. The methodology was thoroughly tested and used to remove low level particulate from the secondary mirror. A decision relative to cleaning the primary mirror will be made in June of this year.

After cleaning for particulate contamination, measurements of molecular contamination will be taken to determine the extent of degradation of reflectivity in the ultraviolet region, which is expected to be very small. A device has been developed to measure direct reflectivity of the primary mirror surface in the ultraviolet region. To create a medium in which ultraviolet waves can travel, it will be necessary to contact the mirror surface to establish a nitrogen environment between the mirror and the measuring device. The contact will be limited, however, to the outside annulus of the mirror which is not utilized during observations.

One of the greatest challenges to be faced during all subsequent phases of the Hubble Space Telescope assembly, test, checkout, and transportation is assuring adequate contamination control. To minimize the possibility of molecular contamination, all components which are located in such a way that they could contaminate the optical surfaces will be vacuum-baked. All cleanliness control measures have been reviewed, and the training, equipment, procedures, and monitoring equipment at all clean room areas have been upgraded.

The primary mirror will be covered after cleaning for the remainder of the program, except during brief periods of essential assembly operations and optical tests, which will occur in a clean room where the mirror is stored. A tight-fitting cover, which does not contact the optical surface, will be placed on the primary mirror until the mirror is integrated into the Optical Telescope Assembly. After that, the structure will provide protection. During transportation from Perkin-Elmer, Danbury, Connecticut, to LMSC, Sunnyvale, California, the Optical Telescope Assembly will be enclosed in a container that provides environmental and contamination control. When integrated into the Hubble Space Telescope, the structure and aperture cover will provide protection. During transportation to the Kennedy Space Center, the Hubble Space Telescope will be enclosed in a container that provides environmental and contamination control, the operation of which is continuously monitored. During launch operations the Hubble Space Telescope will remain covered until just before the Shuttle payload bay door is closed.

The primary technical challenges and schedule risks remaining to the Optical Telescope Assembly project are the successful completion of the integrated Fine Guidance Sensor/Optical Control Sensor testing, and final assembly, alignment and integrated testing of the entire Optical Telescope Assembly.

Support Systems Module

The Support Systems Module, as shown in Figure 4, is being developed by the Lockheed Missiles and Space Company, Sunnyvale, California, and provides the basic spacecraft services including pointing control, electrical power, data management and thermal control. The Support Systems Module also includes the primary structural elements that accommodate the assembly of all systems into the complete spacecraft. These major structures include the forward shell, Figure 5, and the light shield, Figure 6, which provide major structural support to the mirror systems, shield the mirrors and science instruments from extraneous light sources, and provide support for external appendages such as the solar arrays and antennas. The aft shroud encloses the science instruments.

The manufacture and assembly of all structural elements have proceeded close to schedule, however, some elements have been slipped to 1985 without impact to the overall schedule. The light shield and the forward shell were successfully integrated, Figure 7, and the mechanical interfaces verified.

LMSC is currently engaged in functional testing of the equipment section of the Support Systems Module. The equipment section, shown in Figure 8, contains the support elements, such as electrical power, communications, and attitude control that are needed to make the Hubble Space Telescope a functioning observatory. Installation and checkout of the wiring harnesses that connect the major electronic "black boxes" in the equipment section were successfully completed. Most of the

electronic boxes to be housed in this section have been installed. The equipment section has been moved to the vertical assembly and test area, and the verification test phase has been initiated. The equipment section functional test will verify the operation of the majority of the electronic assemblies and interfaces among these subsystems. The test will also provide the first validation of the LMSC automated test equipment and test software that will be used throughout the progressive acceptance and verification testing until the entire system has been verified and accepted. After the equipment section functional test, the science instruments will be connected to the equipment section, and their operations and interfaces will be verified. This will be followed by structural stacking of the Support Systems Module for interface compatibility testing. Upon delivery of the Optical Telescope Assembly from Perkin-Elmer, final assembly of the Hubble Space Telescope will begin late this year, followed by a series of systems-level functional and environmental tests of increasing complexity.

The problem areas reported in last year's testimony dealing with flight software and the availability of computer memory margin, possible spacecraft disturbance by the high gain antenna pointing system, the design errors in the data interface unit, and electrical power margins have all been successfully resolved. In addition, Lockheed has completed construction and certification of the new facility to support the Hubble Space Telescope Project. The high bay test area shown in Figure 9 is one of the largest clean rooms in the country. The major test support stands have been completed and installed, and the Science Instrument Receiving and Inspection Depot has been completed.

The manufacture and assembly of the major electronic assemblies are nearing completion; however, these operations have been and continue to be among the most schedule critical items in the Lockheed effort. This is particularly true of the data management and electrical power systems. The complexity of these assemblies has required more time for the manufacturing and assembly operations than anticipated, and problems encountered in the checkout phase have required modifications and rework. Schedule impact to the downstream assembly and verification phase of the Support Systems Module will be minimized by utilizing functionally tested but not yet qualified electronic assemblies and program spares for use during the assembly and verification phase. Qualified flight units will be phased back into the test operations after completion of qualification acceptance testing of these units. While some schedule risk may exist because problems could occur during these qualification tests, this approach allows us to proceed with the assembly and verification program using functionally proven hardware while concurrently performing qualification acceptance tests.

Major subcontractor hardware deliveries have occurred on schedule with the exception of some elements of the Pointing Control System. Some component failures occurred during the qualification acceptance testing of the pointing safemode electronics assembly, the rate gyro assemblies, and the reaction wheel assemblies. Corrections have been made on the pointing safemode electronics assembly, and only completion of the qualification acceptance test program remains. The relay problem in the rate gyro assemblies is under investigation. The first two units were completed successfully, but a problem occurred on the third unit. We are trying to determine whether this is a random part failure requiring repair of only the failed unit, or a failure that is inherent to the design or

manufacture that would necessitate a redesign. The rotor control electronics was redesigned to reduce a dynamic problem caused by high frequency voltage cycling in the reaction wheel assembly. As indicated, the above deficiencies are being corrected and impact to the assembly and verification phase will be minimized by the utilization of spares and/or engineering models while the flight assemblies are reworked.

Schedule delays have been experienced in the installation and checkout of the Electrical Ground Support Equipment. Figure 10 depicts a portion of the ground support equipment. Ten of the 12 major consoles have been delivered to the test area and are in the integration and checkout phase. A recovery schedule, utilizing extended work days/weeks, has been placed in effect for completion of this equipment to support the automatic test phase of assembly and verification to begin in mid-June. However, it is assessed that there is a two-to-three week threat to the planned start of the automatic functional test. In addition, a problem was recently encountered in cleaning the vacuum chamber that is used to bake-out the Support Systems Module. This bake-out is being rescheduled and could have some impact on the integrated testing schedule. A second shift verification activity will be added to recover the schedule should the need materialize. This added activity would result in a small cost increase that can be satisfied within available project reserves.

The schedule risks resulting from potential difficulties in completing electronic assemblies, test software and electrical ground support equipment as discussed above, represent the greatest concerns on the Lockheed effort. While some risk to the schedule remains, recovery plans have been defined and are being implemented so that the Hubble Space Telescope assembly and verification schedules can be maintained. The overall planning for this phase of the program has progressed satisfactorily, including planning for the science instrument pre-assembly and verification test which was incorporated into the program during the last year to reduce schedule risks to the verification testing. Also, the assembly and verification phase of the program has been modified to allow end-to-end verification of the entire operational system. This verification will include the "real-time" generation of a precursor observing program at the Science Institute, the transmission to GSFC, the generation of spacecraft commands at GSFC, the transmission of these commands to White Sands, thence to the TDRS, and on to the spacecraft at Sunnyvale. Data taken from the Hubble Space Telescope will be received at the Science Institute through the same network described above. The assembly and verification test program represents a very significant and complex phase of the Hubble Space Telescope project which is a finite schedule risk.

Systems Engineering and Integration

Increased emphasis on Systems Engineering and Integration continued during the last year. In addition to the project-level systems engineering office that I discussed in last year's testimony, fully staffed systems engineering functions have been established within the past year for each major element; i.e., Optical Telescope Assembly, Support Systems Module, Science Instruments, and Solar Array. This additional effort has enhanced our ability to assess and meet program requirements in the most cost effective way.

The main elements of these Systems Engineering and Integration activities continue to be the evaluation of the requirements allocated to the various project levels; the performance of interface and design audits; the coordination of a project-wide cleanliness control plan and contamination budget; and the overall coordination and integration of assembly and verification plans. This latter activity has included the interaction with the Principal Investigators during the recently concluded science instrument verification and acceptance program. This coordination provided important lessons that will be applied during subsequent testing at LMSC.

The program requirements have been reassessed and audited, and to date, we have found no instances where the flight hardware will not meet the established requirements. A rigorous assessment of verification requirements was made to assure the timeliness and completeness of verification activities.

Design audits of the major project element interfaces and hardware are underway. While some of this activity remains to be completed, we are accelerating this effort and plan to complete these audits in June 1984. The emphasis to date has been on schedule critical items (e.g., the Optical Telescope Assembly and the Solar Arrays) but all elements are undergoing audit. As an example, a functional incompatibility that could have prevented operation of the Solar Array drive assembly was identified during the audit of the Support Systems Module and Solar Array, and corrective action is being taken. Areas that are still being assessed include fuse utilization and transportation of all project elements.

Solar Arrays

The Solar Array system which is being provided by ESA, is nearing completion. Several of the electronic assemblies have been delivered to LMSC for integration with the Equipment Section in support of the verification program. The Solar Array meets the original power specifications and requirements for the 2½ year orbital lifetime established at the beginning of the program. However, recent studies indicate that the margin of available power over requirements as a function of orbital life is less than desirable. This is amplified by our most recent power system analysis that indicates that the overall system efficiency will be less than originally planned. Furthermore, new requirements may be dictated by the addition of structure heaters to resolve temperature incompatibilities, the addition of latch heaters, and the new emphasis to increase the orbital lifetime to reduce maintenance and refurbishment cost. Accordingly, design options that provide added electrical power were studied by MSFC and LMSC with support by the ESA. The design selected from these studies will provide a 10 percent increase in power margin. The current solar cells will be replaced on the array blankets with more efficient cells. The new design will allow parallel fabrication of replacement blankets that can be substituted for the existing blankets with no hardware impact to the program. This approach also allows maintaining the current system should any unforeseen problems occur with the fabrication of the new blankets.

Science Instruments

There are five science instruments, four being developed by the United States and one, the Faint Object Camera, by ESA. The United States Science Instruments, the Faint Object Spectrograph, the High Resolution Spectrograph, the High Speed

Photometer, and the Wide Field/Planetary Camera, are being developed under the direction of GSFC. Dr. Noel Hinners will discuss the status of each instrument in more detail. Although problems were encountered, environmental acceptance testing on the individual science instruments and verification acceptance testing of all instruments have been completed. The completion of these tests is a major accomplishment in the development of the science instruments. The science instruments are now in a period of refurbishment and recalibration/retest prior to delivery to LMSC later this year to begin final assembly and verification with the overall Hubble Space Telescope systems. There does remain, however, a risk that some of the instruments will be delayed because of their required refurbishment.

MISSION OPERATIONS

The Mission Operations Ground System includes the Hubble Space Telescope Operations Control Center facilities at GSFC as well as all mission operations support software and systems other than those provided by the Science Institute. Ground systems elements and control center capabilities and facilities are well along in development. Dr. Hinners will cover this in more detail.

Space Telescope science mission operations will begin after three sequential periods of orbital verification are accomplished. These periods are: (a) orbital verification of the basic spacecraft systems; (b) ground/flight systems compatibility and operability demonstration; and (c) verification of science instrument calibration and operability demonstration.

An orbital verification and operations team, which was previously planned, has been formed to develop the orbital verification planning. This effort, under the purview of MSFC, is progressing on schedule.

MAINTENANCE AND REFURBISHMENT

The Maintenance and Refurbishment Program has previously assumed both orbital maintenance and ground refurbishment. Maintenance and refurbishment goals and requirements are currently under assessment. It has been determined that more extensive on-orbit Shuttle repair would significantly reduce the maintenance and refurbishment cost below that required for the originally planned ground return approach. This prospect has become more attractive with the potential of having a space station in orbit. Therefore, we are making design changes to increase the number of components that can be replaced in orbit. Examples of hardware items that have been designated as orbital replacement units since my last report are the DF-224 computer, pointing control reaction wheels and solar arrays.

Other critical elements of the Maintenance and Refurbishment Program are the procurement of additional science instruments, the development of space support equipment, and the ground support operations for orbital maintenance. The second-generation science instrument Announcement of Opportunity has been completed and is scheduled for release in July 1984. Detail maintenance and refurbishment planning has been initiated at LMSC and Perkin-Elmer to assure that the plans are in place to store and maintain all ground support hardware and flight spares. Additionally, planning is proceeding for the maintenance and refurbishment data base which provides the necessary documentation to support the Maintenance and Refurbishment Program and the sustaining engineering effort.

The MSFC in-house activities being performed in support of the Maintenance and Refurbishment Program include design and development of Space Support Equipment to be used to service or repair the Hubble Space Telescope on-orbit and to house the spare units being carried to orbit by the Shuttle, Neutral Buoyancy simulations of on-orbit maintenance tasks, definition of on-orbit maintenance procedures and development of the sustaining engineering effort. The Space Support Equipment is proceeding satisfactorily toward a Preliminary Design Review in September this year. To minimize costs, the design incorporates a pallet from the Spacelab Program and the Flight Support System from the Solar Maximum Mission Program.

SCHEDULE AND BUDGET ASSESSMENT

During the FY-1984 hearings, I reported that delivery of the Optical Telescope Assembly was expected in November 1984, with launch of the Space Telescope in the second half of 1986. Although there remain some threats to the schedule established last year, it appears that these dates will be achievable unless major problems are encountered.

The project is progressing well and is within the estimated run-out costs of $1175 million.

The project automated management information system, which should greatly enhance project visibility of technical performance, cost and schedule, will be completed this year.

The planned maintenance and refurbishment activities are currently under review to determine the most cost effective and efficient method of long term maintenance and repair of the Hubble Space Telescope.

MANAGEMENT ASSESSMENT

The Space Telescope management structure discussed with you last year is in place and performing well.

The MSFC Optical Telescope Assembly Project Manager and his staff have continued on-site at the Perkin-Elmer facility and have provided effective on-site management and oversight of the Optical Telescope Assembly activities. A majority of these personnel will return to MSFC when the Optical Telescope Assembly is delivered to LMSC. The remaining personnel will continue on-site until all the Fine Guidance Sensors are completed in 1985. The Perkin-Elmer management team has developed good, detailed schedules and has motivated its employees to work to these schedules. Perkin-Elmer has developed a high degree of schedule awareness and is controlling both its manpower and costs within plan. Considering the challenges of the Optical Telescope Assembly project, I am pleased with the performances of both the MSFC and Perkin-Elmer teams.

The recent schedule performance at LMSC has been less than desired. A number of activities are underway to improve this situation, including increased management visibility, work-arounds, rescheduling lower priority tasks to later dates which are still consistent with the need dates, and working extra shifts. Also, the MSFC Support Systems Module Project Manager and a large portion of his staff have moved to the LMSC facility, Sunnyvale, California, earlier than planned to provide management oversight of day-to-day contractor operations. Since a similar arrangement was very effective at Perkin-Elmer, we are following the same approach at LMSC. Although LMSC has made some organization changes that will strengthen its Space Telescope organization and some of the supporting organizations, further improvements are required and anticipated.

CONCLUSION

In conclusion, I would like to stress that substantial progress has been made since my report last June. The Optical Telescope Assembly is essentially on schedule, and the outlook is good for delivery of that assembly to LMSC as planned. While LMSC has experienced some problems on the Support Systems Module, positive steps have been taken to enhance the capacity to meet project schedules. Significant progress has been made on the science instruments, and there is confidence that these instruments will be delivered to LMSC on schedule. Although challenges remain as the project continues through the critical integration and verification phase, sufficient flexibility has been provided to overcome reasonable unforeseen problems. All indications are that the Hubble Space Telescope is still on schedule for launch during the second half of 1986.

The Marshall Space Flight Center and the entire Hubble Space Telescope team continue to be committed to the successful completion of the Project.

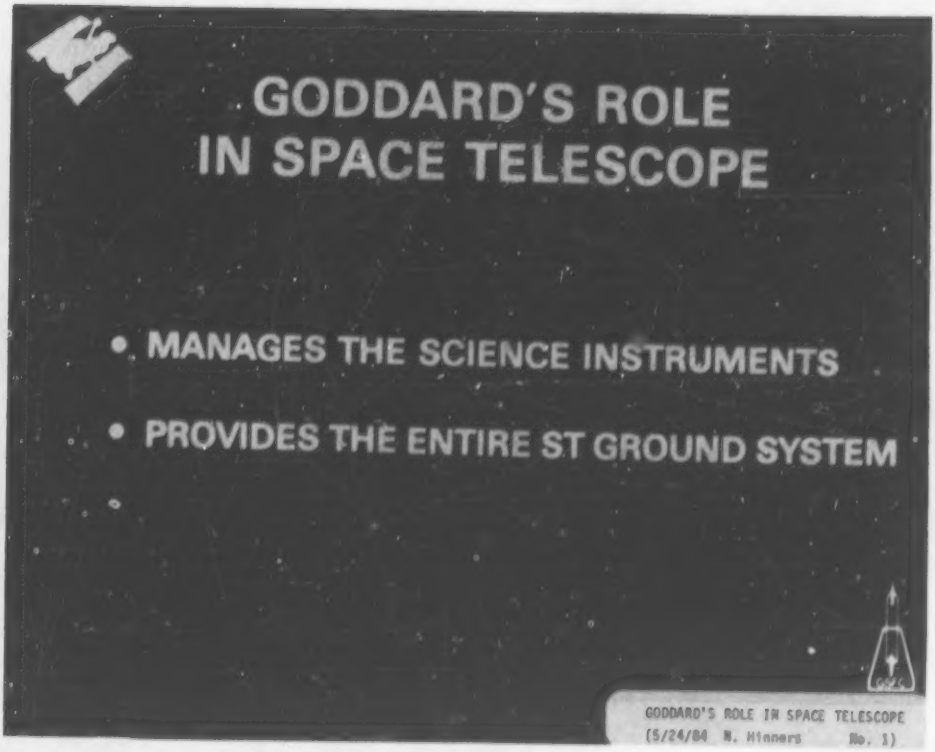
Mr. Chairman, this concludes my prepared testimony, and I will be glad to respond to any questions you may have.

Mr. VOLKMER. Thank you very much, Dr. Lucas. I will now hear from Dr. Hinners. Your statement also will be made full a part of the record. You can either summarize or go through the statement in full, however you desire.

Dr. HINNERS. Thank you.

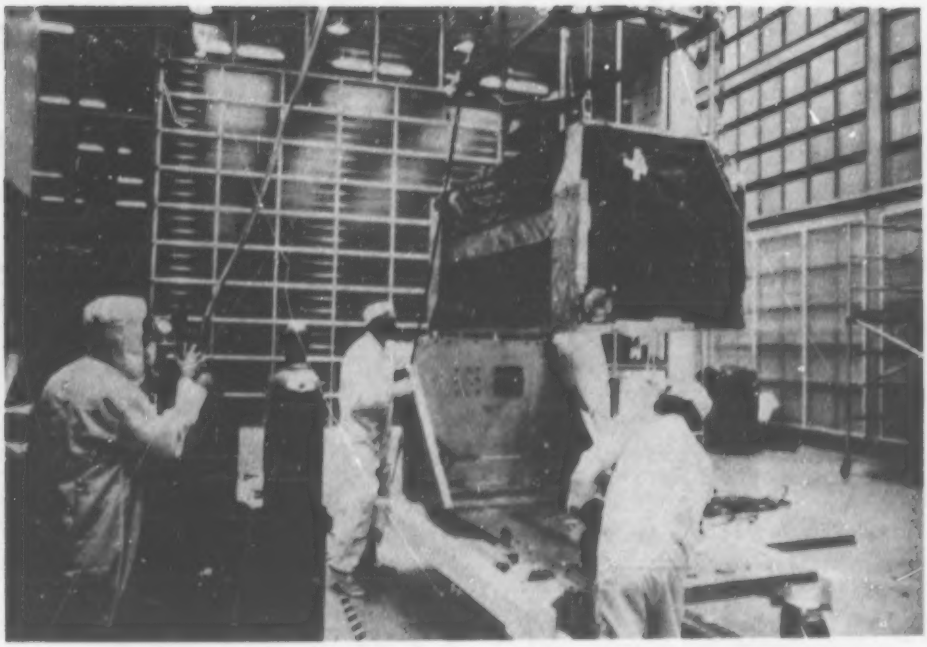
With your permission, Mr. Chairman, I would like to talk to the charts up here.

Mr. VOLKMER. Just a moment, Dr. Hinners. We have one little problem where we do this, and that is, with the reporting—we can take care of this.


GODDARD'S ROLE
IN SPACE TELESCOPE
• MANAGES THE SCIENCE INSTRUMENTS
• PROVIDES THE ENTIRE ST GROUND SYSTEM
GODDARD'S ROLE IN SPACE TELESCOPE
(5/24/84 N. Hinners No. 1)

Dr. HINNERS. The Goddard role [figure 1] in the space telescope is to manage the scientific instruments and to provide the space telescope ground system. We work with this, of course, very closely in conjuction with the Marshall Space Flight Center in the development, looking to that handover period shortly after launch.

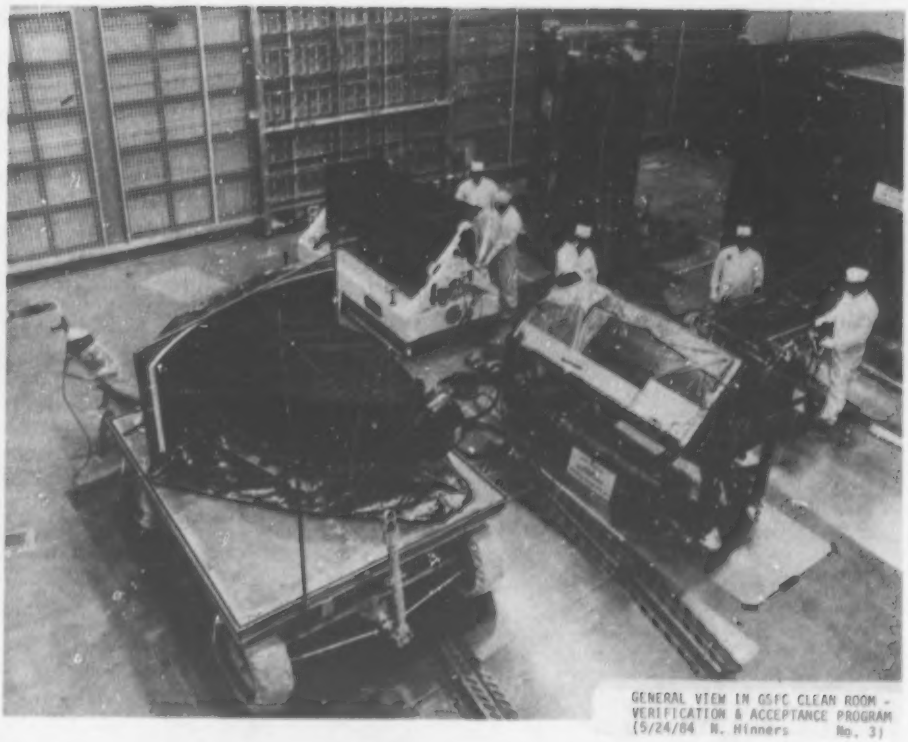
Next, please [figure 2].



HIGH RESOLUTION SPECTROGRAPH
ARRIVES IN GSFC CLEAN ROOM
(5/24/84 N. Hinners Sp. 2)

About 1 year ago, we received the first scientific instrument at Goddard, the high-speed photometer. There are five instruments, as you have been told. The last instrument, the faint-object camera, came in in November, for the verification and acceptance program. When the last instrument came in, we worked the schedule, planned for it to be completed by the end of March, April 1, completed the verification acceptance program by the 21st of March of this year.

Next, please [figure 3].



GENERAL VIEW IN GSFC CLEAN ROOM - VERIFICATION & ACCEPTANCE PROGRAM (5/24/84 N. Hinners No. 3)

This is a photo of the complete complement of scientific instruments at Goddard, where the four axial instruments, the radial instrument, the wide-field planetary camera, and the scientific instrument command and data handling system. Recall the purpose of the verification and acceptance program is to check out functionally each instrument separately to look at the interaction of the instruments with each other in the combined operations mode, to check their compatability with the command and data handling system, with the computers in that system, and with the flight software.

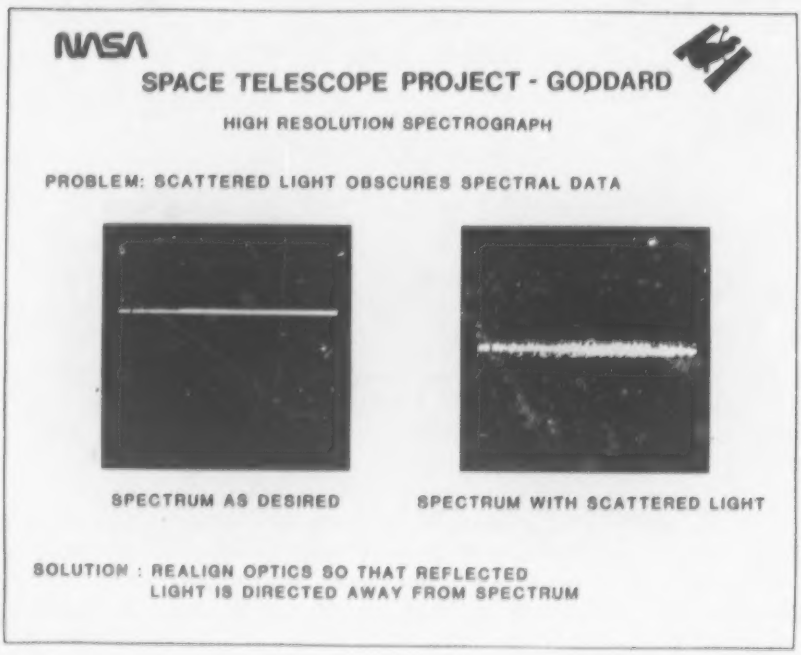
We are happy to report today that the testing has gone very well. The instruments are indeed compatible with each other, with the command and data handling system, its computers and flight software. Along with the normal testing that we did on this, we took a special look at the computers. These are our IBM computers, similar to those which the STS line had problems on, if you recall. Indeed, we did find one that needed replacing that was a potential in there of a very small chip putting that part of the computer system out of commission. We feel now that we do have a well-screened system ready to go for the space telescope.

This last year, we made the decision to produce what is called, by acronym, a STAR, the scientific—the Space Telescope Axial Replacement. It is a dummy axial instrument. If we have any problem during the acceptance and verification test out at Lockheed or potentially on orbit downstream, we will have this dummy instrument that can be used to temporarily replace one of the working instruments while it is repaired, refitted for the space telescope.

We do not have an equivalent replacement for the wide-field planetary camera. We are now looking at whether or not there should be a second wide-field planetary camera produced for the long-term, or whether or not there will be other second-generation instruments to replace these in the long-term planning of the space telescope preparations.

The intent now is for NASA to issue an announcement of opportunity this summer to take a look at what second-generation scientific instruments should be produced for the space telescope, and the wide-field planetary camera resolution, whether or not it is a backup to that, should occur probably within this next year, in conjunction with that announcement of opportunity.

Next, please [figure 4].


NASA
SPACE TELESCOPE PROJECT - GODDARD
HIGH RESOLUTION SPECTROGRAPH
PROBLEM: SCATTERED LIGHT OBSCURES SPECTRAL DATA
SPECTRUM AS DESIRED
SPECTRUM WITH SCATTERED LIGHT
SOLUTION : REALIGN OPTICS SO THAT REFLECTED
LIGHT IS DIRECTED AWAY FROM SPECTRUM

HRS - PROBLEM: SCATTERED LIGHT
OBSCURES SPECTRAL DATA
(5/24/84 N. Hinners No. 4)

We knew, prior to these instruments coming to Goddard, that we had some problems with the instruments. The decision was made not to fix those problems before the Verification and Acceptance Program, because we knew we would find additional things needing fixing during the Verification and Acceptance Program.

So we said, let's get through testing, make all of the fixes after. We are now in that rework period, retest, recalibration for the instruments, prior to the delivery for Lockheed late this summer. Here is an example of some of the kinds of problems that have shown up. The high-resolution spectrograph, an actual instrument, should give us a signal with nice, clean edges. What we found in testing is that we have scattered light coming into the instrument,

which gives this confusion on top of the spectrum that you would like. What we have got to do now is to realign the optics to keep the reflected light from landing on top of that spectrum

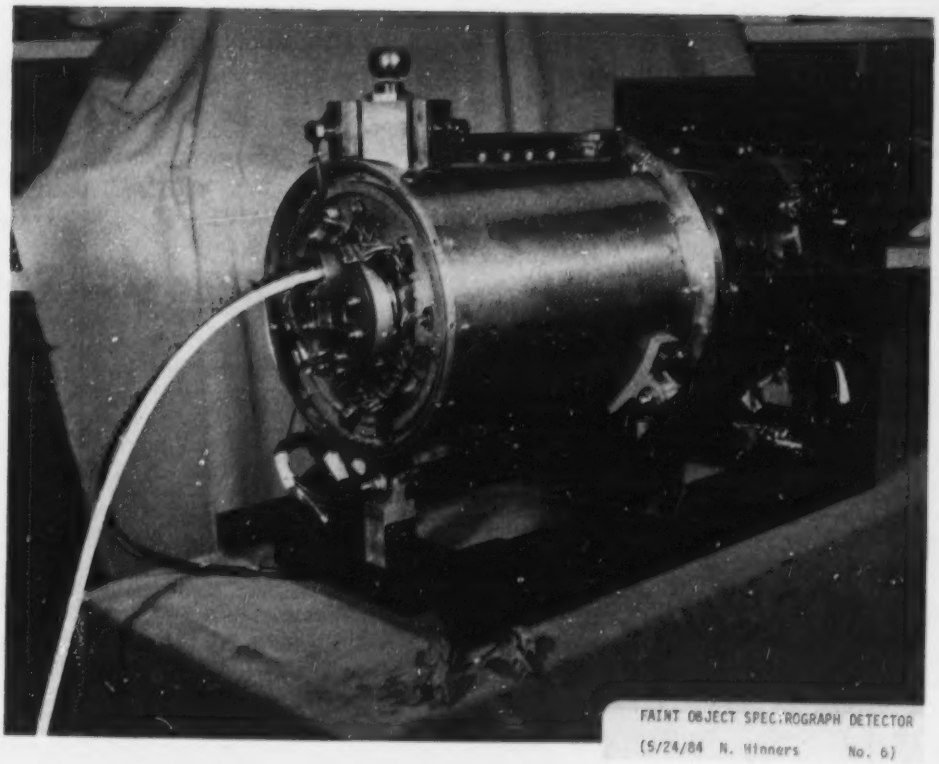
Next, please [figure 5].

NASA
SPACE TELESCOPE PROJECT - GODDARD
HIGH RESOLUTION SPECTROGRAPH
PROBLEM: DATA MISSING FROM ECHELOGRAM
NOTE MISSING DATA IN UPPER LINE
CAUSE: MISALIGNMENT OF OPTICAL ELEMENT
SOLUTION: REALIGNMENT (AND RECALIBRATION)

HRS - PROBLEM: DATA MISSING FROM ECHELOGRAM
(5/24/84 N. Hinners No. 5)

Another problem which showed up was incomplete data in the spectrum. Again, it is a problem of alignment of the optics, so that is underway now. The high-resolution spectrograph is looking as if it will be the last instrument delivered to Lockheed. We are looking at a November delivery. The other instruments will all be earlier. We are seeing, on the Lockheed A&V schedule, that we can work around that and don't expect the late delivery of the HRS to impact the Lockheed schedule.

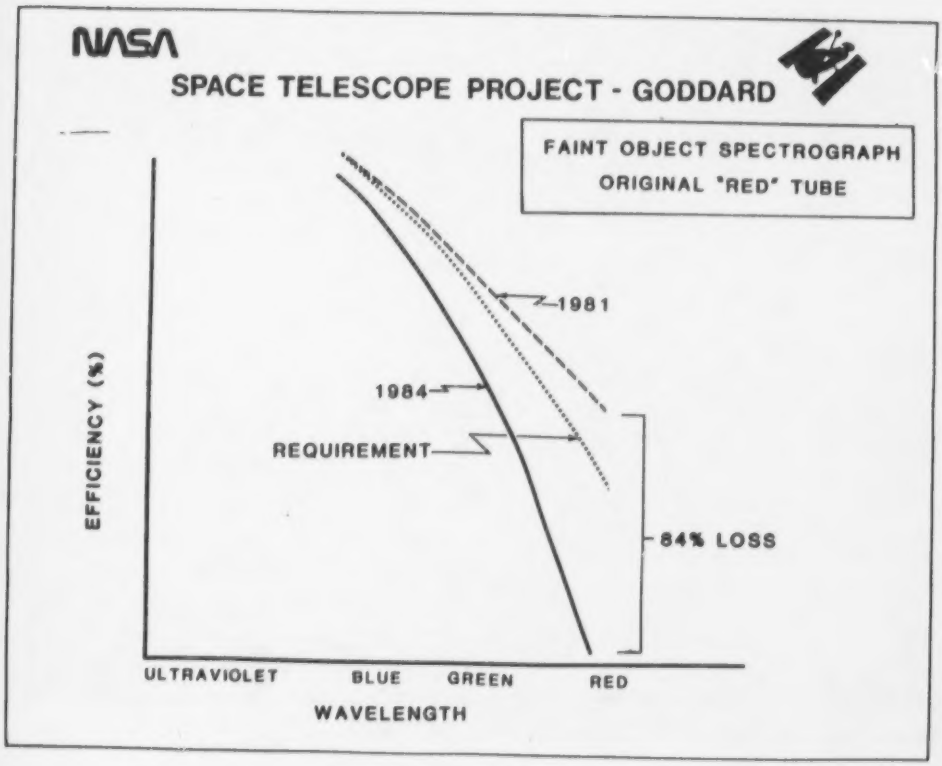
Next, please [figure 6].



In the faint objects spectrograph, we noted last year that we were concerned about the detectors. I just wanted to remind you that when we talk about a detector on the space telescope instruments, they are not just little pieces of the instrument, but this is the detector assembly in the faint object spectrograph. Rather massive; about 70 pounds, well over a foot in diameter, very complex detector assembly. The kind of problem we have run into, that is shown on the next viewgraph. It is a response of the red tube, as we call it, on the FOS. In 1981, a response curve, when we went from the ultraviolet to the red, was performing above specification. It was a steady degradation of this tube, so that by early this year, it was well below the requirements.

I have done the analysis on this, and it has been determined that that would be an unacceptable detector for the FOS. We are in the process of changing that detector. We are not out of the woods yet on that. There are signs of problems with the other detectors in that, and that remains to be solved. We are actively working that.

Next, please [figure 7].

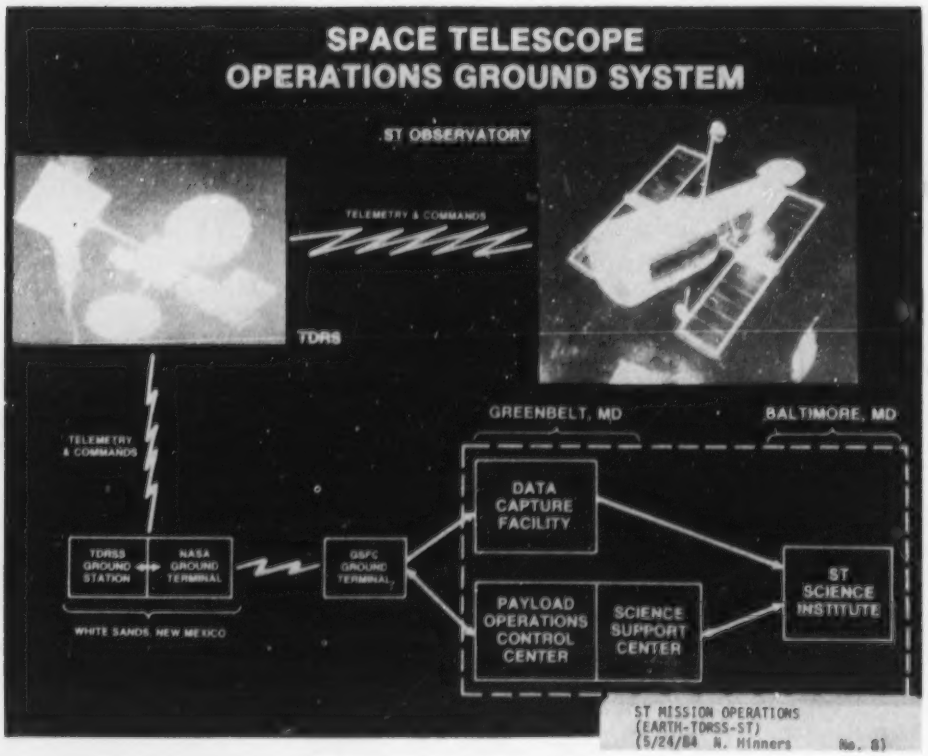


FOS RED DETECTOR TUBE PROBLEM
(5/24/84 N. Hinners No. 7)

On the ground system, we have two components: Engineering operations ground system, and the science operations part of the ground system. Recall, we do go from the telescope, both directions, through the TDRS system, tracking and data relay satellite system, down to the ground station at White Sands, through DOMSATS, to the Goddard Space Flight Center, where we have the operation at Greenbelt, with the Payload Operations Control Center, data capture, the science support center jointly manned between Goddard and the Institute. Then, the Space Telescope Science Institute up at Hopkins. One of the areas that we have not talked much about, but which is still a concern, is the completion of the TDRS system. The telescope is dependent on the existence of a complete TDRS system. As you know, we have one up there now. We are looking now at a February 1985 launch for the second TDRS, and about 4 months later for the third. But we are on a schedule now, so when the IUS comes through, for a completed TDRS system by next summer, which would be plenty of time for the telescope launch a year later, but still something we are keeping an eye on.

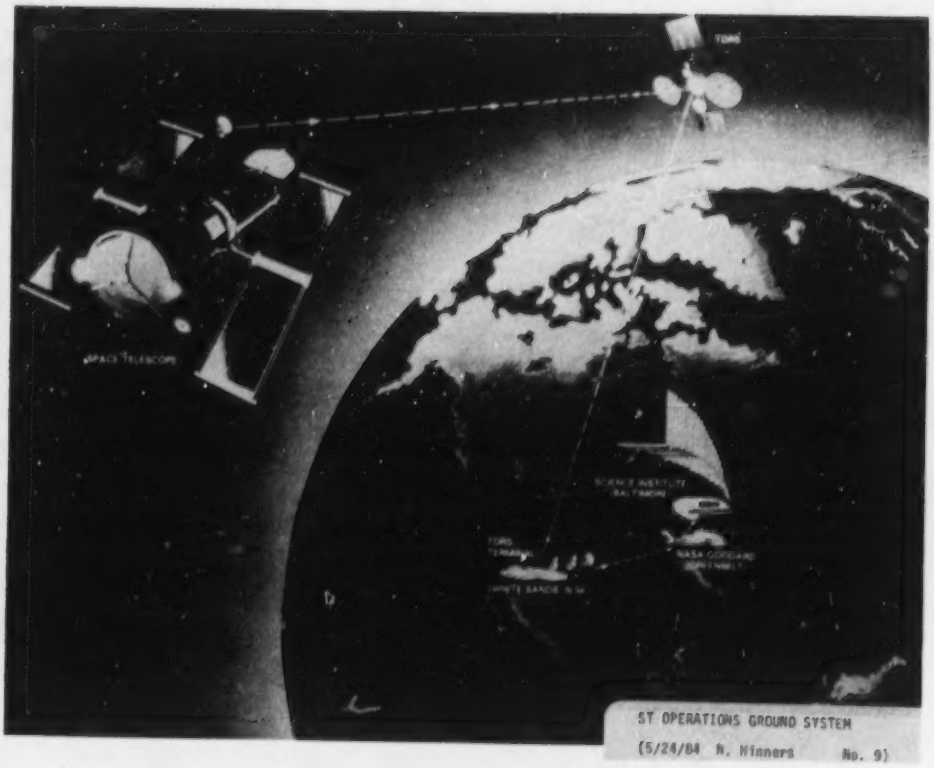
In the ground system, the data capture facility and the Payload Operations Control Center are coming along in good shape.

Next, please [figure 8].



In February of this year, we dedicated the Payload Operations Control Center at Goddard. The software, the computer systems, the operations, are on schedule for the launch of the telescope. We see no problem at this end. This part is funded by the Office of Tracking and Data Acquisition.

Next, please [figure 9].



The Science Operations Ground Systems, SOGS, I am not going to go into detail on this, but it does give you some indication of the complexity of this science operations ground system, starting off, essentially, when we are up and running, with proposal submission; evaluation; through the guide star selection; to be sure that we have guide stars to work with a particular target; getting through the commands, through the POCC, through the Payload Operations Control Center at Goddard, through the spacecraft, the TDRS system; getting engineering feedback; looking in real time at both the engineering data, the science data, as it is coming in; working through the Institute for the data capture and analysis; finally delivering products to the scientists; and allowing them to interact both in person at the Institute and through remote activity, through what will eventually become the data archiving system.

Now, the various portions of this are being both produced by TRW and the Space Telescope Institute. The SOGS system was started before the Institute came into being. The complex part of the system involved a lot of the actual development of the guide star selection system, the science planning and scheduling system, the science data analysis system.

The guide star selection system, and the science data analysis system, have been very highly dependent upon the Space Telescope Institute personnel. It has required a combination, if you will, of astronomer-software developer, to be sure that that system produces a working system for the space telescope, one optimized for the science return.

Because of the late arrival, if you will, of the Institute on the scene, that part of the system has been the leading schedule problem in the development of the SOGS. We are sensibly comfortable now, not totally, that the SOGS system at TRW and the Institute is on a schedule which will get us to the delivery date to the Institute of October of 1985.

Next, please [figure 10].

ST OPERATIONS CONTROL CENTER (STOCC)

(5/24/84 N. Hinners No. 101

This just gives you some feel for the different pieces of the SOGS system. I mentioned the science data analysis guide star selections, which are being done by the Institute personnel.

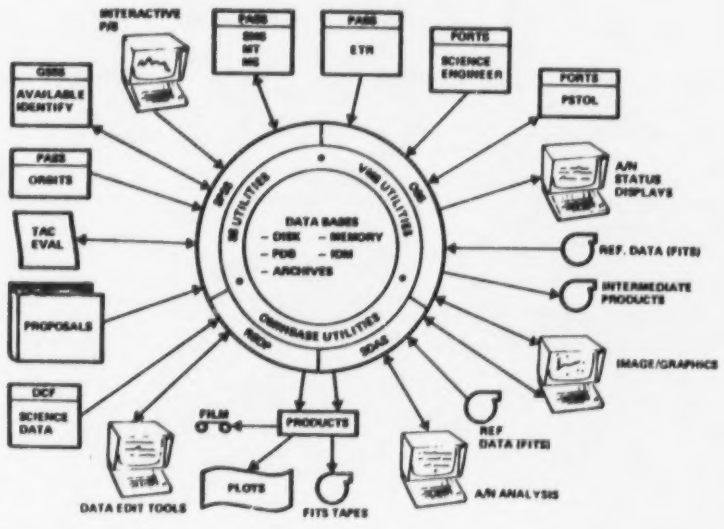
All the delivery dates here come in next summer with a total system turnover in October 1985. As I believe Sam Keller mentioned earlier, we are concerned about some of those schedules, the guide star selection system being one of them, and are working very closely with the Institute to assure that gets delivered on time. There is agreement, I think, that we will have a SOGS system which will be available and operating and will support your early launch of the space telescope in good shape. We realize that the SOGS system that is now under development, will not be the complete system, the final system.

Next, please [figures 11, 12].

NASA

SPACE TELESCOPE PROJECT - GODDARD

SOGS EXTERNAL INTERFACES



ST OPERATIONS GROUND SYSTEM -
EXTERNAL INTERFACES
(5/24/84 N. Hinners No. 11)

NASA

SPACE TELESCOPE PROJECT - GODDARD

SCIENCE OPERATIONS GROUND SYSTEMS

FUNCTION	CURRENT STATUS	DELIVERY
SCIENCE PLANNING & SCHEDULING (2 PARTS)	CODE & UNIT TEST, FINAL DESIGN	MARCH 1985, JULY 1985
OBSERVATION SUPPORT	INTEGRATION & TEST	OCTOBER 1984
POST OBSERVATION DATA PROCESSING (2 PARTS)	INTEGRATION & TEST, FINAL DESIGN	DECEMBER 1984, MAY 1985
HARDWARE (2 PARTS)	OPERATIONAL, ON-ORDER	DECEMBER 1984, JUNE 1985
SCIENCE DATA ANALYSIS	BUILD 3 OF 5 BUILDS	SUMMER 1985
GUIDE STAR SELECTION	CODE & UNIT TEST	JULY 1985
SYSTEM TURNOVER		OCTOBER 1985

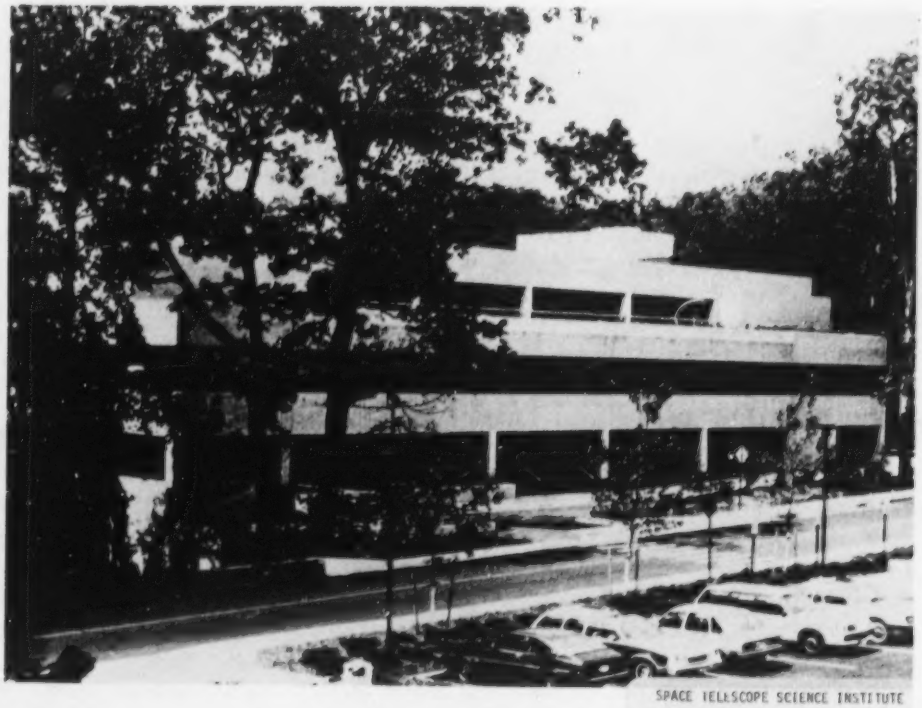
ST OPERATIONS GROUND SYSTEM - STATUS
(5/24/84 N. Hinners No. 12)

We are looking at an evolution of the SOGS system for two reasons: One, we do not now have the funding or time, probably, to complete that system. Examples are the complex moving target selection and some of the software systems involved in the astrometry. Those will be implemented in an evolutionary fashion up to and during, after the launch period.

We also know that in the instrument development, the instrument operation, when we get down to operating, and a software checkout, when we get on orbit, that new things come up, new ways of operating. So we expect and anticipate a steady evolution of the science operations ground system.

That will be part of the ongoing operations of the space telescope.

Next, please [figure 13].



SPACE TELESCOPE SCIENCE INSTITUTE
(5/24/84 N. Hinners No. 13)

Mr. VOLKMER. Dr. Hinners, I am going to have to interrupt at this time. We might have to recess. We have another vote on, and this is a little bit more important one than the last one. So I have to run. We will recess for about 10 minutes.

Dr. HINNERS. Fine.

[Recess.]

Dr. HINNERS. Continuing on——

Mr. VOLKMER. Before you do, I would just like to announce for everybody here that is with the Government, including yours truly, that it looks like you will be getting a paycheck. The increase in the debt limit passed the House by a few votes.

Dr. HINNERS. What we have here is the Space Telescope Institute Building up at Hopkins. You have probably heard a fair amount about the Institute and its relationship to the SOGS and the operation of the telescope.

My assessment is that overall relationships with the Institute are quite good. That is not to say that we don't have points that we are in discussion about, and I will talk about them in a minute. The Institute is well-staffed now. They have very competent astronomers, software managers, and we are happy with the progress of that and their relationship in working with us at Goddard and with TRW on the development of the SOGS.

I do want to remind you that both for us and for the contractor, AURA, it is a new mode of operation, and we continue to feel our way out in terms of how best to deal with this mode of operation. It is a consortium of universities. It is an institute responsible for the scientific operations of the telescope. It differs in the sense that

NASA has not operated in this mode before at all, and on the consortium side, on the Institute side, it is different from their standard method of dealing with the National Science Foundation Program.

With the National Science Foundation, the usual way is for NSF to contract for actual design, development, operations of the complete facility, such as the Kitt Peak Observatories or the National Radio Astronomy Observatory. Then, NSF awards the grant money to the individual astronomers who use those facilities. And the equivalent institute then is concerned mainly with scheduling the facilities.

Where we differ is that the Institute is an integral part of the total system, where NASA has the responsibility for the development of the hardware and the Institute is playing an integral role in the end-to-end space telescope system. The second place where it differs is that the Institute will actually be responsible for the funding of the individual observers and the selection of those observers. This different kind of relationship dictates, in my view, a different kind of overall NASA responsibility, as contrasted with the National Science Foundation. It does mean that we must be more intimately involved in and have more oversight of the Institute functions.

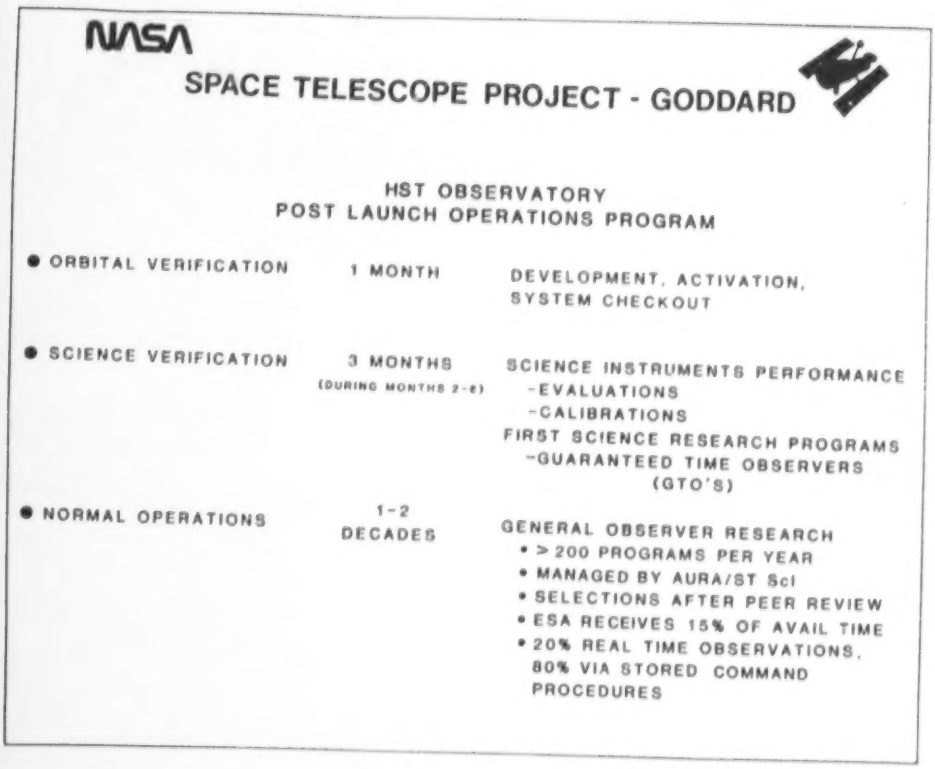
I believe we are on a good path to establishing those relationships and understanding of what those must be. The main item of contention now—and I say this, keeping in mind that on most fronts, I think things are going well—is the eventual size of the staff and the facilities of the Institute.

We are in very good agreement on the specific functions which the Institute is to accomplish. Where we differ is in the magnitude, the manpower associated with specific functions. And that is simply going to be a matter of negotiation and trying to understand in detail how they are operating, how we operate, and most importantly, what the overall budget constraints are. We are in very close and frequent discussion with the Institute on this. We have recently—NASA has recently asked the National Academy to put together a committee, which I believe Art Code is going to chair, to look at the long-term size and scope of the Institute.

We realize that there will be a peak in manpower loading just prior to and during the launch phase, but we want to assure ourselves and the science community that the Institute is understood by all of us and is, as they say, under control, because we realize in the operating timeframe that there will be constrained dollars.

We have got to look very carefully at the distribution of those dollars between our mechanical operations, if you will, and the support of the science community for the data reduction, the data acquisition, the guts of the science return, if you will.

Next, please [Figure 14].



ST POST-LAUNCH OPERATION PROGRAM
(5/24/94 N. Hinners No. 14)

To finish up, I just wanted to remind you of what we are looking at at the end of the actual hardware development phase. Right after launch, we have orbital verification, which is a 30-day checkout period of the space telescope, primarily looking at the telescope systems, the engineering activity, to be sure that everything is working as we wanted to, and is performing according to specification.

After that 1-month nominal checkout, we are going to a 5-month period, which we call science verification. The 3 months here is the actual 90 days, if you will, of science verification activity. It is spread over 5 months because this period, there would be several months' equivalent where the instrument development teams get their observing time, and we get the first science back from the program. That is dedicated observing time to those people who have now—or will have—put in close to a decade of devoted and dedicated time to getting those instruments ready.

So, if you will, that is their pay for participating in getting those instruments ready for the space telescope. After a half a year, we go into what we call the normal operations, and are planning for that one to two decades of operations.

As you have heard before from Bill Lucas and Sam Keller, we are looking very hard at optimizing the on-orbit repair and maintenance, as contrasted to bringing it back for ground refurbishment,

which all of us feel is an inefficient way to go, if we can possibly avoid it.

In summary, I feel we are in good shape, we are integrated with the rest of the development program at Marshall, with Perkin-Elmer and with Lockheed, and I believe that we will have the ground system, both science and engineering operations, in shape, ready to support the launch in 1986.

Thank you.

[The prepared statement of Dr. Hinners follows:]

Statement of

Noel W. Hinners
Director, Goddard Space Flight Center

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

Subcommittee on Space Science and Applications
Committee on Science and Technology
House of Representatives

Mr. Chairman and Members of the Subcommittee:

This statement presents the current status of the development of the Space Telescope (ST) Science Instruments, the plans for orbital replacement of instruments after launch, the science operations ground system, the scope of responsibilities of the ST Science Institute, and the post-launch operations program.

Introduction

Let me begin by giving you the progress and achievements which have been made since my last appearance before the Subcommittee on June 14, 1983. In so doing, I will also describe any new problems that have arisen since then.

Science Instruments Progress

All five of the Science Instruments were delivered to Goddard, the last of which arrived last November. The objective was to functionally test the Instruments with the flight Command and Data Handling system, to verify their operation with the flight software contained within the computer of the Command and Data Handling system, and to verify the mutual compatiblity of the Instruments when operating simultaneously, as they will often do in orbit. This effort required nearly a year to complete, involved 12 contractor teams totalling perhaps a hundred people or so, and represented one of the major tasks for the ST Project in 1983/early 1984. I am especially pleased to be able to report to you today that this activity was successfully completed on March 21, 1984--some 10 days in advance of the date established upon delivery of the final Instrument some 5 months earlier.

Now that this testing has been concluded, the Instruments have been released back to their manufacturing groups to perform the necessary rework, recalibrations, and retest prior to their delivery to the ST Assembly and Verification phase at the Lockheed Missiles and Space Company. This rework period became necessary largely as a result of the discovery of technical problems within the Instruments prior to their delivery to Goddard last year. In my testimony of last June, I cited several such examples, involving the High Resolution Spectrograph, the Faint Object

Spectrograph, and the High Speed Photometer; the corrective actions for these problems are now underway. These problems involved a high noise level of one of the High Resolution Spectrograph detectors, the degradation of the red detector of the Faint Object Spectrograph, and the design and construction defects associated with a vendor-supplied power supply for the High Speed Photometer. Additionally, several new problems have been identified and their corrective actions defined. These actions will be implemented as well. These include a problem with an aperture mechanism of the Wide Field/Planetary Camera, high-voltage capacitors and memory of the European Space Agency's Faint Object Camera, optical performance and second detector of the High Resolution Spectrograph, and other minor problems. With only one exception, all of these additional problems are being attended to without the need for additional funding or schedule relief.

The exception involved the High Resolution Spectrograph, specifically its optical performance and its second detector assembly. Additional analysis of the High Resolution Spectrograph test and calibration data revealed an unacceptable optical performance, along with unacceptable performance of the second detector assembly, similar to that which had been discovered and reported earlier. The corrective actions for these were debated thoroughly within the Project since, if they were to be done, the High Resolution Spectrograph would not be ready in time for the preliminary phase of the testing at Lockheed. It was determined that it is essential to correct the spectrograph problems and, further, that the 2-month effort could be done so as to not impact the overall ST schedule. These actions are provided for within our existing project funding reserve. In summary, our present approach calls for time-phased delivery of five fully-capable Instruments to Lockheed beginning in August, and ending with the High Resolution Spectrograph in November. All will have been reworked and retested as necessary to restore them to their full scientific potential and qualification standards.

We, too, are rescreening certain electrical components of the memories of our flight computer as a safety measure, due to its similarity to the Shuttle computers which experienced two internal particle-induced failures in a previous mission (STS-9). To date we have discovered the existence of one conductive particle that conceivably could have caused a failure of up to one-eighth of our on-board memory capacity.

We continue to be concerned about the performance of the digicon tubes of the Faint Object Spectrograph, especially the one that covers the red region of the spectrum. Although the quantum efficiency of the replacement Red Digicon has remained stable, recent tests have shown an increase in its ion count, giving rise to a concern about the longevity of the tube. We are conducting additional tests on similar tubes to establish the cause of the change and to evaluate its impact on long-term performance. Monitoring of the planned flight red tube continues.

In summary then, the Science Instrument development effort this spring and summer is being devoted to some rework and retest. While we have several problems and concerns, we expect that the Instruments will be delivered to Lockheed as required by the overall ST schedule.

Replacement of Science Instruments After Launch

One of the principal characteristics of the ST, which distinguishes it from the spacecraft of the past, is its ability to capitalize on the utility of the Shuttle through the means of on-orbit servicing, repair, and even upgrading. In the current era of expanding technology, it is clear that new and advanced instrumental techniques will continue to emerge. The "plug-in" design of ST allows, for the first time, the upgrading of the science capability of the Observatory with techniques and hardware that do not exist today. [Of course, it will also be possible to remove a failed Instrument for ground refurbishment and to subsequently return it to orbit, thus restoring the capability of the ST Observatory. Although we do not have contractual arrangements to perform repair at this time, the option exists should it become necessary and prudent to do so.]

Returning to the topic of Advanced Science Instruments, NASA plans to issue an Announcement of Opportunity in July of this year, soliciting domestic and foreign proposals for advanced science investigations and associated instrument hardware. We will begin with the selection of four to six of the most promising proposals for a detailed study phase, with final selection for the hardware phase deferred until about one year after the ST launch. This will permit an evaluation, based on early science results, of the most promising areas of science or techniques to be pursued. The end result of this process will be the availability of one, perhaps two, NASA-funded Advanced Science Instruments, and perhaps one funded by the international community about 5 years after the launch of ST. The new "Advanced Science Instruments" would represent mid-80's technology, or about a decade newer than the present set of five Science Instruments to be launched. The newer technology, combined with the lessons learned from early science return, will permit the avoidance of obsolescence as the Hubble Space Telescope operations move into the 1990's, and even beyond.

One of the Science Instrument contingencies that cannot be addressed by the Advanced Science Instruments, especially during the first five years after launch, is that of the "unthinkable," which is: What are the consequences, should an early catastrophic failure occur in one or more of the prime-science, original Science Instruments? Since, as the recent Solar Maximum Repair Mission has spectacularly demonstrated, the Shuttle servicing capability does indeed exist, should we be prepared with a Science Instrument repair capability--just in case? The Project has given serious consideration to these questions, including the likelihood of failures, and the steps and resources that would be needed to become prepared. Some limited steps have already been taken, including the beginning of fabrication of an inert axial replacement "instrument" (we call it "STAR," for ST Axial Replacement" module), that could be temporarily inserted into the ST either on-ground or on-orbit, pending repair and return of the failed axial instrument. We believe that STAR, which will be ready about 1 year before launch, could prove to be an exceptionally valuable "stand-in," should a repair become necessary on one of four Science Instruments during testing before launch.

Other possibilities are being considered, such as the construction of a duplicate Wide Field/Planetary Camera, since that Instrument is likely to be the prime-science producer in its own right, as well as providing a supporting role to the operation of the other Instruments. Of course, funding for this capability has never been a part of the ST plan; but nevertheless many of us believe that compelling arguments can be made, based on science return-on-investment, that strongly favor the provisioning of this contingency capability. NASA has not yet concluded its assessment of this concept, and indeed it may be determined that it is not now feasible.

Science Operations Ground System

Goddard's second major responsibility is to provide the entire ground system for ST. We can think of this effort as an "engineering operations ground system" and a "science operations ground system," the latter being more troublesome due to its extensive and largely-pioneering nature. The engineering operations ground system continues to make excellent progress toward completion, with all hardware and most of the incrementally-built software already in place and ready for testing.

The overall ST requirements and expected capabilities are rapidly converging toward the final science operations ground system configuration, largely as a result of consensus obtained within the entire ST community. The scope and complexity of the science operations system encompasses the entire end-to-end system, from the earliest science planning of observations, all the way through science data collection, to final analysis and product creation. Important progress was made in this system in the past year: a recovery process was instituted for one particular subsystem (Science Planning and Scheduling System), a number of crucial detailed studies were initiated (including data archival and distribution, and astrometry data flow and handling), and staffing and resources allocation changes were made to correct deficiencies and to strengthen our position toward an on-time completion of a fully-capable system at launch.

The contract to implement the majority of the science operations ground system was competitively awarded over 2 years ago to TRW, Inc., of Redondo Beach, California. The TRW contract implements most of the required science operations function; the remaining are being implemented by other contractors and the ST Science Institute. The original contract provides the hardware and software for Science Planning and Scheduling, for Observation Support (which is the real-time science control activity), and for the routine science data processing. Additionally, it provides the basic hardware for all science data analysis, the applications software which is an ST Science Institute development effort. The hardware alone represents about one-third of this contract, including 6 main frame computers and 10 state-of-the-art display systems. Currently, all hardware planned to be delivered at this time is in place and is supporting software development at TRW. The balance will be installed in early FY 1985.

The software systems are in various stages of completion, with some builds planned for test this summer and others throughout the next year. Delivery and installation of these to the operating sites (primarily the ST Science Institute) will start this fall, and final delivery to the ST Science Institute will be completed by October 1985, at least 9 months before launch and in accordance with the plan mutually developed with the ST Science Institute staff.

The other current contract which provides implementation of a portion of the science operations ground system is with the Association of Universities for Research in Astronomy, which operates the ST Science Institute. As mentioned earlier, the ST Science Institute is providing the science data analysis applications software due to the highly-specialized nature of these functions. For the same reason, the initial ST Science Institute contract included the requirement to develop the Guide Star Selection System which includes unique hardware measuring devices, as well as computers and software. These developments are proceeding with some schedule and cost difficulties experienced with the Guide Star activity, but now planned for a 1985 completion.

The systems developed under these contracts will allow us to support nearly all of the planned ST operational requirements, but we have identified a number of additions that we need to make, though not necessarily within the existing contracts. These additions include: the capability to observe moving targets, such as satellites of planets; support of Astrometry science; and the Data Archive and Distribution Service which will store and disseminate the science data after its proprietary status has expired. We have these subjects under active study at this time.

We recognize the need to provide for future enhancements and improvements for the science operations ground system to maximize the scientific productivity of the Hubble Space Telescope Observatory. We realize that some of these enhancements or improvements will have to be based on experience not yet gained or on tests or operations not yet performed, thus we are anticipating a sustained effort over the next decade. First of all, our Civil Service staff will provide continuity to the systems, and we will engage our development contractors in "sustaining engineering" level-of-effort arrangements as needed. The goal is to eventually create the "well-oiled," scientifically-productive machine that will fulfill the great expectations commonly held for ST.

In retrospect, it is obvious to us that the currently planned science operations ground system is more capable and in better schedule status than ever before. The Science Planning and Scheduling System has undergone a recovery process that responds to needs identified by members of the ST Science Institute. Almost 3 million dollars of added effort was put into the TRW contract, and this has become the overall pacing item for the final delivery. However, the status today and the schedule outlook for the remainder of the initial effort satisfy us that we have a viable plan, with a capable team, and that the extensive organization and personnel changes within the Goddard management team are paying off.

Space Telescope Science Institute

In 1976, the National Academy of Sciences sponsored a study to consider the benefits of creating an institute for the scientific exploitation of the ST. Under the leadership of Dr. Donald Hornig, this study committee recommended to NASA that such an institute would enhance the scientific productivity of the Observatory. Its purpose would be "... to provide the long-term guidance and support for the (ST) scientific effort, to provide a mechanism for engaging the participation of astronomers throughout the world, and to provide a means for the dissemination and utilization of the data derived from ST."

As proposed by Dr. Hornig, "... the institute should be of sufficient size, in facilities and staff, to carry out its functions, but should not become so large as to absorb an inordinate fraction of the resources devoted to astronomical research. (It)... requires a first-rate central staff which, through its own involvement in research with the ST, will ensure the optimum use of the telescope..." The Hornig Committee also explored the practical implementation of such an institute and estimated its appropriate size to be from 120 to perhaps 200 persons.

The following year, NASA examined several alternative forms of the institute proposed by Dr. Hornig. The conclusions of the NASA study embraced most of the Hornig Committee recommendations.

In 1981, Goddard awarded a contract to the Association of Universities for Research in Astronomy to establish and operate the ST Science Institute. Through agreement with the Johns Hopkins University in Baltimore, the ST Science Institute is housed in a new facility on the Homewood campus and enjoys access to University services and the academic environment.

It should be noted that, for NASA, such an institutional arrangement for the conduct of science is without precedent; hence, lacking a model, some evolution in the role and size of the ST Science Institute was inevitable. But, the basic purpose and character of the ST Science Institute today remain faithful to the National Academy of Sciences recommendations; and NASA and Goddard are committed to its success.

In a similar manner, it should be noted that for the Association of Universities for Research in Astronomy, the ST institutional arrangement is also unfamiliar. In the past, they have been exclusively engaged in the operation of national ground-based observatories under the auspices of the National Science Foundation.

Some significant differences exist between the way in which the National Science Foundation operates ground-based research facilities and the way NASA intends to operate ST. Both agencies make use of scientific consortia to administer the science operations, but differences arise both in areas of technical and operational responsibility and also in responsibility for the scientific reseafch program. In the case of the National Science Foundation facilities, a consortium is funded to design, construct, maintain, and operate the facility, so that responsibility for all aspects of the facility itself is funneled through the consortium.

With regard to the science program, the consortium selects users of the facility by means of competitive proposals and assists the users in obtaining their data; but, in order to obtain funding for data analysis and subsequent research, the user must apply to the National Science Foundation directly.

In the case of ST, NASA itself has managed the hardware development program and contracted directly for construction of the spacecraft, telescope, Science Instruments, and the operations ground system. After launch, NASA will retain responsibility for the safe operation of the hardware, for monitoring its engineering performance, and for carrying out maintenance and repair efforts as needed. The responsibility of the consortium operating the ST Science Institute will be to select users through a peer review process, to schedule their observations, to oversee the scientific aspects of spacecraft operations, and to provide the users with data analysis tools to assist in the interpretation of the observations. Moreover, the ST Science Institute will be provided a budget identified exclusively for the financial support of user research and will be responsible for administering these funds.

NASA intends to maintain close and detailed management and oversight of the ST Science Institute because of two significant reasons: 1) the intimate technical relationship between the ST Science Institute's science operation activities and NASA's overall operation and maintenance of the ST facility, and 2) by delegating to the ST Science Institute the authority to provide financial support of ST users, NASA has greatly increased the consortium's responsibility and influence over the conduct of scientific research, as compared to the National Science Foundation mode of operation.

The ST Science Institute exists primarily to manage the ST research program through selection of ST users; to conduct science operations of the ST Observatory; and to provide staff and facilities to serve the user community. The contract with the Association of Universities for Research in Astronomy provides for research by its scientific staff to maintain their individual qualifications and skills. ST Science Institute scientists may propose observing programs using ST or other observatories, but no privileged access to the ST is provided. The research activity of the ST Science Institute is not intended to compete with the university community. The ST Science Institute is engaging in certain system development and enhancement activities (described above), for which it is uniquely qualified, but most operational support systems are developed and provided by NASA through contracts with industry.

The ST Science Institute is currently developing the capability to operate the science aspects of the Hubble Space Telescope Observatory and its versatile Scientific Instruments. The mechanism to solicit and evaluate observing proposals from the science community is under development. Many of the supporting capabilities and services needed to operate the Hubble Space Telescope are being developed by the ST Science Institute. These include instrument operating procedures, instrument calibrations, a guide star catalog, and a data analysis system. Good progress has been achieved in these technical areas, and the ST Science Institute has a complete and functioning administrative support capability.

One problem area that we are currently working with the ST Science Institute is that of the required post-launch staffing level and its effect on the yearly operating budget. The present NASA staffing projection in the operational era is approximately 250 persons, plus visiting scientists and general observers. The forecast of the ST Science Institute is some additional 30-50 man years per year. While both of these projections are substantially higher than initially projected by both Dr. Hornig and NASA, much of the growth is truly needed to productively operate and maintain this very complex observatory. The current problems center around just how much is truly needed. However, we recognize that every dollar spent on in-house staff at the ST Science Institute is a dollar that is unavailable to support the acquisition and analysis of science data by astronomers. Therefore, we are striving to achieve an optimum balance: to provide the required service capability within the ST Science Institute, while preserving the essential research support funding available for the general astronomy community.

Post-Launch Operations Program

The operations program for ST is formally separated into three phases: Orbital Verification, Science Verification, and Normal Operations. The first 2 phases together constitute the commissioning of ST as an astronomical observatory; the third phase will be devoted primarily to carrying out the research program for which the observatory was built.

Orbital Verification is defined to be a 30-day period immediately following launch, during which the ST is deployed, its various subsystems activated, and its engineering performance characterized. The ST Project in conjunction with its contractors will specify the detailed tasks to be performed during this period. The objective by the end of Orbital Verification is to have a functional telescope, spacecraft, and ground system.

Science Verification is defined to be a 90-day effort, distributed over 5 months, during which the performance of the science instruments will be evaluated, calibration performed, and techniques developed for using the observatory to collect scientific data. The detailed tasks to be performed will be specified primarily by the scientists of the Instrument Definition Teams. The full 5 months will be filled out by interleaving Science Verification tasks with the first research observations to be taken by ST. These observations will form part of the data guaranteed to the Instrument Definition Team scientists, and the early results from these observations should serve to demonstrate by the end of Science Verification that the ST Observatory is an operational research facility.

Normal Operations will start with the observations of the first ST General Observer. General Observers will be selected semi-annually by the ST Science Institute on the basis of peer-reviewed research proposals. The selection process for the first General Observers will begin about 1 year before launch. The ST Science Institute staff will assist General Observers in the detailed planning of their observing programs and will have the responsibility for scheduling these observations, collecting the data, and transforming it into a form suitable for scientific analyses.

The General Observers can be present, at their option, at the ST Science Institute during observations, but their presence will be essential for only about one-fifth of the observing programs requiring real-time interaction between the ground and the telescope, in order to achieve the objectives of the observer. After the calibrated data have been delivered, the General Observers will generally use the facilities of the ST Science Institute to begin interpretation of their data, and they may continue using these facilities via distributed data processing networks even after they have returned to their home institutions. All ST Science Institute data analysis software is being designed for maximum transportability.

Science Return

The prime motive for launching and operating ST is the increase of scientific knowledge, and we are developing the ground system and operational facilities to provide a suitable environment and the resources necessary for that endeavor. The intense anticipation of the astronomical community, together with the competitive process for selecting ST users, ensures that ST research will be of the highest quality. However, we believe that is not enough. Therefore, it was decided some years ago to establish, under the auspices of the ST Science Institute, and advisory group (the ST Advisory Committee) of scientists to provide guidelines for the overall science program of ST, particularly with regard to achieving a suitable balance among the various subdisciplines of astronomy and between short-term versus long-term investigations. These guidelines will help us to be sure that the research program of the ST observatory remains pertinent to the major scientific issues and that the observatory is used for problems suitable to its unique capabilities.

The rate at which results will be produced is difficult to anticipate and will be heavily influenced by the balance that is adopted between short-term and long-term observing projects. While difficult to predict, the science rate of return will also be difficult to measure. One typical technique used in the past, however, is the use of published results in the scientific literature. One may expect analyses of ST data to start appearing in scientific journals in significant numbers, starting about a year after launch. Based on experience with previous astronomical satellites, the publications should increase exponentially until 2-3 years after launch as the unique capabilities of ST become fully exploited; Thenceforth, papers resulting from ST should have an influence on the astronomical literature comparable to or greater than those from the major national ground observatories.

In addition to the careful and considered analyses of ST data requiring months or even years to produce, we can reasonably expect to receive some exciting, "gee-whiz" kinds of results on occasion in near real time. This can be likened to the "instant science" which has occurred with each of the planetary encounters of recent memory.

It should be pointed out that ST will live up to its full scientific potential only if it is long-lived. Only if the observatory lasts for an extended number of years with relatively stable performance characteristics will it be possible to collect the large quantities of data necessary to address questions regarding the expansion rate and curvature of the universe, the cosmological distance scale, astrometric evidence for other planetary systems, and other fundamental scientific problems that require the ST resolution and limiting magnitude. The results from these investigations will come slowly but, in the long run, will constitute ST's most important contribution to science. We plan and expect to operate ST as a long-lived facility and to provide scientists with both the data and the research support needed to tackle these problems.

Concluding Remarks

In summary, the two ST activities for which Goddard has responsibility have made excellent progress over the last year. The Science Instruments have completed their verification testing with their on-board command and data handling and computer system, and all are currently undergoing rework and retest prior to their delivery to the ST assembly phase later this year. The development of the ground system, as well as the means to operate ST, continues on schedule. Significant improvements to the science operations ground system capabilities were adopted and put into place to increase operability and efficiency; and, though a few problems exist, they are neither major nor insoluble, and the remaining efforts to meet fully the defined ST requirements are becoming sufficiently well defined to permit their implementation by launch.

I will conclude my testimony with the same thoughts as last year; namely, that we plan to provide Science Instruments fully capable to deliver promised and perhaps unimagined science, and we will provide a ground system which is fully capable of exploiting the potential of those Instruments.

Thank you very much, Mr. Chairman.

Mr. VOLKMER. Thank you very much, Dr. Hinners.

We will now proceed with questions. In general, I would like to say I appreciate all of your testimony here today. I can say that I guess, before we get into specific questions, after reviewing the testimony yesterday and this morning, and after the testimony just 2 days ago, Tuesday, some of the scientists—maybe I have a little more concern than you do over some of the problems that we have, and maybe we can get into those specifics.

Before I do, though, I recognize the gentleman from Florida if he has any questions.

Mr. NELSON. You are very kind, Mr. Chairman. I appreciate it. Good morning, gentlemen. I apologize for being like a jack-in-the-box up here, but if you think it is bad this morning, you should have seen it last night. It is good we didn't have the hearing last night, or else we would have accomplished absolutely nothing.

I would like to ask Dr. Edelson and Dr. Lucas some questions about the putting the telescope up in the proper orbit.

According to your previous testimony, you need to put it up about 320 miles. Now, what do you need to do to the shuttle to reach this altitude?

Dr. LUCAS. We don't need to do anything to the shuttle to reach that altitude. We expect to put it at that altitude by direct injec-

tion from the shuttle to 320 nautical miles. That will be a single payload, however, it will take the capability of the Shuttle to do that.

Mr. NELSON. And that is using the 110-percent engines?

Dr. LUCAS. No, sir, it will not be using the 109-percent engines. It will not—I believe it will not require the 109-percent engines; 104.

Mr. NELSON. Any lightened orbiter, such as the filament wound casings, or anything? Just go in with what you have.

Dr. LUCAS. That is right, sir.

Mr. NELSON. OK, now, what is the lowest altitude that you can let the observatory drift to?

Dr. LUCAS. We would—when it gets to about 300 nautical miles, we would want to reboost.

Mr. NELSON. So just a degradation of 20 miles?

Dr. LUCAS. That is right.

Mr. NELSON. From 320 down to 20.

Dr. LUCAS. That is correct.

Mr. NELSON. All right, with the integral shuttle propulsion system, how high can you reboost it?

Dr. LUCAS. Well, we can reboost it to 320 miles again.

Mr. NELSON. What happens if it comes down much lower? With that system, how high can you reboost?

Dr. LUCAS. That is about the limit——

Mr. NELSON. 20 miles.

Dr. LUCAS. Right.

Mr. NELSON. I yield to the gentleman.

Mr. VOLKMER. What is the timeframe estimated for it to drop that 20 miles?

Dr. LUCAS. Well, of course, that depends on the solar activity, and that varies. It turns out that the time that we are going to launch the space telescope, the solar activity is predicted to be at a minimum.

So it would not be required, we think, in less than probably 2 years, at the least.

Mr. NELSON. All right, I want to question that, because we have gotten some information that it was going to have to be reboosted every 9 months after that.

Dr. LUCAS. I don't have any—I don't think that is correct. I have no knowledge that that will be the case.

Mr. VOLKMER. If the gentleman will yield, I was under the impression that we were going to have do it in about a year and half after the launch, and then every 9 months thereafter, at 320.

Dr. LUCAS. As I say, that depends upon the solar activity, but I don't believe we forecast solar activity that would bring that about.

Mr. VOLKMER. I yield back to the gentleman from Florida.

Mr. NELSON. So you are looking at a reboost about every 2 years.

Dr. LUCAS. I would say that is based upon what we anticipate solar activity, that would be about the order of magnitude.

Mr. NELSON. OK, when we originally planned this project, the telescope project, did we plan that we were going to have to reboost?

Dr. LUCAS. Yes, sir.

Mr. NELSON. All right, if we wanted to reduce the frequency of that reboosting, what could we do?

Dr. LUCAS. We could, of course, put it to a higher altitude, but that we would require us to reboost less frequently. We hope, of course, that with the coming availability of an orbital maneuvering vehicle, which would be stationed at a space station, for example, that this reboosting would be a very simple matter, and would not require the shuttle.

Mr. NELSON. You just put an orbital maneuvering vehicle up there on it, as it degrades, you just lift it back up.

Dr. LUCAS. Lift it back up.

Mr. NELSON. And you do it frequently instead of waiting every 2—do you do it frequently or do you wait until the end of 2 years, and then you put it back up?

Dr. LUCAS. We would probably put it higher in the first place with that kind of a system.

Mr. NELSON. OK.

Dr. LUCAS. And then, how frequently, we would have to go back—that would be dependent upon the solar activity.

Mr. NELSON. OK.

Now, until we have that capability, why did NASA drop the orbital maneuvering system, OMS capability supplemental kit, so that it could get up higher, and thus have less frequent boost? The OMS systems.

Dr. LUCAS. I don't know that we are the right people to answer that question, but I am not aware that we have dropped the OMS system. The OMS system is a fundamental part of the shuttle, and it hasn't been dropped, to my knowledge.

Mr. NELSON. We are talking about a supplemental, aren't we talking about additional fuel? We are talking about additional fuel in order so that you can get it higher than 320, and thus, not have the frequency of having to reboost. Can you share any of that with me?

Dr. EDELSON. I fear we are the wrong people to answer that question, Mr. Nelson, but we will get the proper answer and submit it for the record.

Mr. NELSON. OK.

[The information follows:]

The original approach to meet anticipated requirements for orbital altitudes above the basic Shuttle orbiter performance was the OMS Payload Bay Kit. This approach was never implemented because only two payloads in the STS mission model had requirements beyond the standard orbiter OMS system: the Solar Maximum Repair Mission and the Space Telescope. An alternative mode, the direct insertion method (longer SSME burn), was selected to satisfy effectively these missions without the significant additional development cost of the OMS Payload Bay Kit. In the case of the Space Telescope, the plan is to launch the spacecraft into a 320 nautical mile orbit, and use the Orbital Manevuering Vehicle to reboost the Space Telescope when the orbit decays to about 300 nautical miles. This is currently estimated to be in the late 1988–89 timeframe based on predicted solar activity.

Mr. NELSON. Under what circumstances would you—and please, if you would, Dr. Edelson, I would appreciate it—under what circumstances do you think that you would come back and revisit the observatory for maintenance?

Dr. LUCAS. Under what circumstances? If we have some indication of the deterioration of some of the systems, or if some system becomes nonfunctional, then we would of course revisit and make appropriate repairs.

Mr. NELSON. Are you likely to experience any of those malfunctions?

Dr. LUCAS. In time, we most certainly, I think, will. We, at the outset, when we planned out maintenance and refurbishment program, we anticipated that in about 2½ years, 2 to 2½ years, because that was the time associated with the anticipated life of the kinds of components that would be built in.

And usually, our experience has been that spacecraft systems last longer than we planned for, but certainly, in time, they will deterioriate.

Mr. NELSON. OK. Let me just make sure that my understanding of this is correct. Is there a reason other than the limit—the capability of the shuttle that we should go no higher than 320 miles?

Dr. LUCAS. No——

Mr. NELSON. In other words, if we could get higher, that is better for us.

Dr. LUCAS. That is right.

Mr. NELSON. And the orbit degrades less the higher you are.

Dr. LUCAS. That is correct.

Mr. NELSON. OK. Then I think, falling back on my other question, is that—you have got the capability of having supplemental fuel in the OMS system, to boost you higher. That was axed in being asked for by NASA.

And there is a certain cost that is attended to, as you say, every 2 years, going up there and having to reboost it up, as compared to the cost of the extra fuel in the OMS system to boost it higher than 320 in the first place.

And I am very curious as to why that decision was made not to go with the supplemental? Someone apparently in NASA feels that it was more cost-effective to go up and reboost it every 2 years.

But I would like to question the validity of that in a respectful way. I just want to know what the thinking of NASA was.

Dr. EDELSON. Mr. Nelson, there was a quite a package of Shuttle improvements and upgrades that have been considered for the budgets over the last few years. And I know that it was a budgetary decision, but we are not—this group is not party to know the rationale, and so we will get that for you and submit it for the record.

Mr. NELSON. In an active solar cycle, it would have the tendency of degrading the orbit——

Dr. EDELSON. Quicker.

Mr. NELSON. More quickly, and therefore, the reboost would have to be much more frequent. And it could be as frequent as 9 months?

Dr. EDELSON. Yes, it could be. Yes.

Mr. NELSON. But you have no evidence that we are going to have that kind of active solar cycle?

Dr. EDELSON. That is correct. We feel that we will not, and the—it is during a period of quiet sun, and we have done many studies, including worst cases, and it is our best prediction that it would be approximately 2 years to degrade, let's say, for the orbit to be lowered 20 miles, from 320 to 300.

Mr. NELSON. Mr. Chairman, just in passing, I want to say two things: First of all, the success of this mission is going to be one of

those stellar performances that will again rivet the attention of the Nation, indeed the world, on the value of the Nation's space program.

And second, I wanted to say to Dr. Hinners and his team, what a marvelous job you out at Goddard did with regard to the capture of the last satellite and the—Solar Max. That was just terrific, and how your team on the ground responded with the expertise that they did.

That was an important, very important, PR element for the Nation's space program, and I tell you that from the standpoint of a politician who has to look in the increasing competition in the allocation of dollars up here, as to where they go.

Thank you, Mr. Chairman.

Mr. VOLKMER. The Chair will recognize the gentleman from Washington.

Mr. CHANDLER. Could I defer to you, Mr. Chairman?

Mr. VOLKMER. Sure.

I would like to ask, I guess, several questions, and if anyone wishes to interrupt to anything, they can.

I guess I could start with the basic question, one that I think I know what the answer is going to be, but after reviewing everything with you this morning, do you still believe that the April 1986 or spring 1986 date and launch, early fall, is realistic?

Mr. KELLER. Yes, Mr. Chairman; I do. I think all of us do. Perhaps the best way to look at the progress we have made, and we recited for you this morning a number of problems which are the problems we are addressing today.

If we had have appeared before this committee 2 months ago, you would have had an equally impressive but different list of problems. What we have tried to do is structure a program which is realistic but extremely challenging.

And we have, if you look at our progress over the last year, been in general, 2 or 3 weeks behind schedule all the time.

Now, the important thing is not that we are behind schedule, but do we get further and further behind or not? And I think we have been able to address these problems. We have maintained about the same position. We have not gotten worse.

I think you will continue to hear, for the next 2 years, of a series of problems, and hopefully, we will continue to solve them. We have no reason to think that we will not make that date.

Mr. VOLKMER. Anyone disagree with that?

Now, in the event that there is a delay, if that should happen, what would be the approximate cost per month of delay?

Mr. KELLER. In that last year, we will probably be spending money at the rate of about $10 or $12 million a month. The real question would be what would the cause of the delay be, because effectively, we are paying for manpower. And if it were a delay at the launch site, where you did not have large contractor teams, that is one thing.

If it occurs early on in this integration test cycle, and we have large numbers of people standing around and additional work to be done, it could be at the normal spending rate. It is a little difficult to project.

Mr. VOLKMER. If, for one reason or the other, one of the instruments Dr. Hinners has checked out and everything, but we do have some problems with a couple—if for one reason or the other, that one of those instruments wasn't ready, even by November, wasn't ready to be integrated, let's say, until December, and then something went wrong with another one, and had to be brought back and reworked, and your 85 days, let's say, is gone, you come—now, what about that?

Mr. KELLER. I think you are posing, sir, a very difficult question. A series of tradeoffs that one would have to make. I am not sure I can hypothetically draw you a date at which we fall over the cliff. But it would have to look at the particular instrument involved, the science return.

As Dr. Hinners mentioned, we have the so-called STAR, which is, in effect, a dummy instrument that we can fly, or one of the axial instruments.

If the delay became great enough, I think the time would come when we would go ahead and launch and then put that instrument on on-orbit during a revisit trip, but I am not sure I can give you a real hard hypothetical answer that says that 6 weeks I do that, and then 4 weeks I wouldn't.

Mr. VOLKMER. Now, you are pretty sure, too, that the—Dr. Lucas, that the optical telescope assembly will be delivered around November 1?

Dr. LUCAS. Yes, sir; we have committed to delivery in November, and I don't have any reason to doubt that. We were a little bit behind on schedule a few weeks ago, but about 3 weeks, as a matter of fact, but 2 of those weeks have already been made up, and we expect to be fully on schedule by June 6, and the team is very dedicated to delivering in November, I believe they will make it.

Mr. VOLKMER. Now, by November, will we have more than the one engineering fine guidance system?

Dr. LUCAS. No, sir; the unit will be delivered with one fine guidance sensor, and there is a schedule for the delivery of three more, consistent with the Lockheed need dates.

Mr. VOLKMER. Now, we are behind in the second one on that, are we not?

Dr. LUCAS. At one time, we did plan to deliver two fine guidance sensors with the instrument, and now we will only deliver one, but we will deliver the second one ahead of the need date at Lockheed.

Mr. VOLKMER. Is Perkin-Elmer going to be able to complete their work without cost overruns? I know everybody's under now, but with the delays we have, that is the cause of it. Now, to catch up, what about——

Dr. LUCAS. We believe—Perkin-Elmer is not forecasting any cost overruns at this time, nor do we have any reason, and specific reason to believe that there will be any. With a program of this nature, it is not—it wouldn't be any more unrealistic to consider some problems, but we do have, I think, adequate budgeting to cover reasonable foreseen problems.

Mr. VOLKMER. The other thing that concerned me during your testimony, you used the word "if," I believe, when—I heard right—

when we were discussing—when you were discussing the cleaning primary mirror. Is it "if" or "when"?

Dr. LUCAS. It is indeed "if" because we have a decision meeting on that early in June to decide whether to clean or not to clean. We have developed a system to clean, we started that last year.

That system has been developed, thoroughly worked out, prepared for, and then a decision will be made early in June if we actually proceed with the cleaning.

Mr. VOLKMER. Do you anticipate that there would be no additional particle contamination?

Dr. LUCAS. No, sir; we don't——

Mr. VOLKMER. Toward 1986?

Dr. LUCAS. We do not make that—we would not make that as an anticipation, and would not make such a statement. We do anticipate that there will be some minor accumulation of contamination.

This problem has been worked very thoroughly by a committee in the last several months, and a budget has been allowed—a reasonable budget has been generated for contamination at each step of the telescope from now until actual launch.

And, so, there is a matter that we are going to have to consider, is the contamination now sufficient added to a reasonable anticipation of additional accumulation of contamination to warrant the time and the expense to make the cleaning?

Mr. VOLKMER. As I understand the cleaning methodology, it was used on the secondary mirror.

Dr. LUCAS. That is right.

Mr. VOLKMER. It was planned to be used basically on a primary mirror.

Dr. LUCAS. That is correct. It has already been done.

Mr. VOLKMER. It was done satisfactorily, what are your concerns about using it on the primary mirror? What the "if"?

Dr. LUCAS. There is, I think, minimal risk, but any time you handle the mirror, which you would have to handle it somewhat, there is some risk. There—the system that has been worked out for this cleaning involves some little jets of gas, high purity gas that would be blown against the mirror surface, and a vacuum system that would pull in the contamination away.

This tool, we might say, has to move within about three-quarters of an inch of the mirror surface. Now, it has been worked out thoroughly, and we have been assured that there is no possible way for that machine tool or that tool to touch that mirror surface three-quarters of an inch away.

But, pursuing our normal conservative approach, we want to be absolutely positive that there is no possibility of that before we make the decision——

Mr. VOLKMER. When that decision is made, I would appreciate your notifying the committee what the decision is.

Dr. LUCAS. Yes, sir; we would be glad to do that.

Mr. CHANDLER. Would the gentleman yield on that point?

Mr. VOLKMER. Yes.

Mr. CHANDLER. I am just curious about what compromises you make in the quality of data collection, without the cleaning, or do we know yet?

Dr. LUCAS. There is very little compromise with the present amount of accumulation. The budget, or the allowable accumulation is a 5-percent aerial coverage of the mirror. We now believe we have 1.4 percent, and that if we live with 5, then 1.4 is of little consequence.

What we are concerned about is not with what we now have, but by providing some little additional margin against the potential of accumulating additional.

Mr. CHANDLER. Thank you, Mr. Chairman.

Mr. VOLKMER. Now, we get out to the Lockheed. Do either the problem with the bake-out—you are satisfied that that can be all overcome with any major time delay?

Dr. LUCAS. Well, there may be some time delay, as I testified. We think we can overcome that time delay. It does require some heaters to heat the telescope itself, or the structure itself being baked out, and that is being done.

We think that the time delay associated with this will be overcome, but there could be as much as 2 or 3 weeks of schedule loss there.

Mr. VOLKMER. Now, will that come out of that 85-day——

Dr. LUCAS. If we don't make it up, it would come out of that 85 days, but we are confident that we can make it up by double-shifting and techniques of that nature.

Mr. VOLKMER. That would delay, also go on through and delay the integration, testing, and everything?

Dr. LUCAS. Well, the SSM testing is proceeding in parallel. That testing is going ahead and at such time as the bake-out chamber is ready, we will simply take it out of test, bake it out and then put it back in. And that is where the delay would occur.

Mr. VOLKMER. Now, what about on the electronic or black boxes? As I understand, there has been a delay on fabrication of some of those?

Dr. LUCAS. There have been some problems in fabrication of black boxes. We believe that now is in hand, and again, we are attempting to overcome any threat to the schedule by utilizing continuing the test program, utilizing other units that are not yet qualified, but that are functional.

Mr. VOLKMER. Yes, OK. The same question as I asked in regard to Perkin-Elmer, in regard to Lockheed, and I understand that right now there is an underrun, but again, we have these problems. Do you envision any cost overrun with Lockheed?

Dr. LUCAS. Well, I would respond essentially the same way as on Perkin-Elmer. There is a very critical program for the next year and a half or so with Lockheed. The program has been laid out with some reserve in terms of time and resources. I have just recently had a very intense discussion with the new general manager of the Space Systems Division of Lockheed, man of great experience in doing the kind of job that we are now doing.

He assures me that he has studied the schedule and that he believes it is a doable schedule, and consistent with the resources available.

I think, though, we have to recognize that when you do something as critical as this A&V test, that there is a potential that we

will find something. And that is wrong. That is the way we do this test.

We have allowed, though, for the normal kinds of things that you would anticipate in a test of this difficulty.

Mr. VOLKMER. Do you believe that the 85 days set aside for the rework is going to be sufficient?

Dr. LUCAS. Yes; we believe it will be sufficient unless we anticipate—we just run into something that just would startle us all. We have about what is viewed to be 15 to 16 months' activity, and we have set aside some 3 months for rework.

Now, this is based upon our completing the work in March 1986, and being ready to launch in June 1986. And of course, we have made a commitment to launch in the latter half of 1986.

Mr. VOLKMER. Dr. Hinners, you mentioned some problems with the faint object spectrograph. You envision that in the future that those problems will be able to be overcome?

Dr. HINNERS. We anticipate that they will, but it has not been demonstrated yet, Mr. Chairman. So it is a concern.

Mr. VOLKMER. And that is with what, ions in the digicon tube—is that correct?

Dr. HINNERS. Right.

Mr. VOLKMER. Your concerns about the longevity of the tube, and the tube is actually degradated, as you show it on the graph, right?

Dr. HINNERS. Correct. We know we have to replace that one. That is the one that was in place initially.

Mr. VOLKMER. Now, do we have any other tubes in the same type, et cetera, red region of the spectrum, that have been running simultaneously?

Dr. HINNERS. Well, that is the one we are looking at now. The one which has the ion current is the one we would use for replacement. Mr. Chairman, at this time, I would like to turn to Dr. Boggess for any elucidation on the telescope.

Mr. VOLKMER. Well, I'd like to know because, you know, what concerns me is not only, to get relative, we have the faint object spectrograph in the telescope and that 3 years from now, the tube goes down. What are we going to do about it?

Dr. HINNERS. I'd like to call on Dr. Boggess to address this.

Dr. BOGGESS. I can only agree with your concern——

Mr. VOLKMER. Just a moment. For the reporter, if you can come up to one of the mikes, just turn it around.

Dr. BOGGESS. First of all, I agree with your concern. As Dr. Hinners said, we do have spare tubes available, and we are evaluating them currently to make sure that similar problems don't exist with them. And that evaluation has not been completed, so I can't say categorically that there isn't such a problem. But the indications at the moment are that we will be able to have a satisfactory spare detector to put in.

Mr. VOLKMER. And if the tube would degradate while it's up there, this does then affect the scientific investigation that's taken place for the use of that instrument, then?

Dr. BOGGESS. Yes; it would. Now, the instrument is a very versatile instrument and will be useful for a broad range of scientific problems. And it would not eliminate all the kinds of science that

would be done, but it would eliminate some of the very important scientists on the faintest galaxies that we're anxious to proceed with.

Mr. VOLKMER. All right. One last basic question, then. And that is, if this did happen, would we have to bring the instrument back here, or could that tube be replaced on orbit?

Dr. BOGGESS. My belief is that it could not be replaced on orbit.

Mr. VOLKMER. Well, we have to bring the whole instrument back?

Dr. BOGGESS. Yes; as has been indicated with the SMM, once you face such a situation sometimes people become very clever. But I don't believe that we would be able to get to that tube on orbit.

Mr. VOLKMER. All right. Thank you very much.

And let's see, we had problems also with the high spectrum didn't we? Huh?

Yes; just a moment.

And on the high-resolution spectrograph the concerns there I guess are not quite as serious as with the other; is that correct?

Dr. HINNERS. That's correct. We think we know the solution, or we know the solution to those. It's a matter of time replacing that and getting it reintegrated, recalibrated and rewired.

Mr. VOLKMER. And then reworked is all that. And we have no problems with the wide-field planetary camera?

Dr. HINNERS. We did have the problem with the apperture on the wide-field planetary. That also appears to be solved.

Mr. VOLKMER. OK. Are there any of the instruments that we would be able to repair in orbit?

Dr. HINNERS. The instruments by and by are not repairable on orbit. The initial design concept was to replace entire instruments in those packages. Getting inside those packages and working with the innards is a tough job right here in our terrestrial laboratories. Again, sometimes we get very inventive when faced with a problem, but by and large we are looking at replacement of those units.

Mr. VOLKMER. Bringing the whole instrument down and taking one up——

Dr. HINNERS. Either taking one up and replacing it with another instrument on that same flight or, if necessary, putting in the structural thermal axial replacement unit as a dummy while it's brought back, repaired, then taken up again.

Mr. VOLKMER. So that would be for the axial but not for the radial type?

Dr. HINNERS. That's correct. We do not have a replacement or a backup for that radial at this time.

Mr. VOLKMER. All right. And that brings me I guess to the next set of questions for Dr. Hinners. And that is, as we look at the timeframe in the announcement of opportunity, as I understand your testimony we probably wouldn't have any instruments from that announcement of opportunity for a minimum of what? Five years from launch? Four years from launch?

Dr. HINNERS. That I think is a good assessment, Mr. Chairman. I'd like to turn to Mr. Keller at this point. That is dependent on funding and the rate at which we proceed on new instrument development.

Mr. KELLER. Well, I think two things. One is, I believe you are probably aware, we are considering but have certainly not made any decision on the possibility of constructing from existing spare systems a wide-field planetary camera as a replacement in case of failure. That probably is our most significant instrument and our principal imaging instrument.

Mr. VOLKMER. When will you be making determinations that you will have——

Mr. KELLER. Well, we will make that determination within the next few—several months, let me put it that way.

Mr. VOLKMER. All right. We have funds available in 1985?

Mr. KELLER. We would be very tightly funded, and it would be a function of how rapidly we would proceed to do that.

Mr. VOLKMER. All right.

Mr. KELLER. But we do not presently have funding planned to develop that instrument. Now, in the event that we should determine to develop a spare wide-field planetary camera, then we would probably postpone the instrumentation of an instrument that would be selected as a result of the announcement of opportunity. The reason being that we clearly could not fund the development of two instruments simultaneously.

I think we will certainly wait until we find the quality of proposals that would come out of an announcement of opportunity. That could become a major factor. We have not addressed this question in great detail in part because the funding options are relatively limited at this point in time and we don't know what we might get out of a request for proposals.

Mr. VOLKMER. What is the anticipated length of life of these instruments?

Mr. KELLER. It is very difficult to say. We very seldom design a lifetime of more than 3 years. You'd normally find those kinds of lifetimes. However, there was a recent study done by the people at Goddard which indicates that the one thing that does not normally fail on a spacecraft is the instrument. We have had instruments lasting in general much longer than the spacecraft. There with five instruments one could develop a statistical probability of failure, and about the only thing I could tell you is that's not the date it would fail on.

We have a relatively small number of instruments here, and I think it is not unreasonable to suspect that the majority will last for a good many more than 3 years.

Dr. HINNERS. Mr. Chairman, there's another consideration on that. Recall when we initiated those we looked on two instruments as being what we call core instruments: The wide-field planetary camera and the faint objects spectrograph. And it's been the assessment—I believe this is still true of the science community—that if one instrument were to fail, again depending on whether it's a core instrument or not, there are so many things to be done that there's a full observing program to be conducted with essentially the core instruments or even any other two instruments.

So we do have some flexibility. It is not—if an instrument does go out, again depending which one it is, there are still a very vigorous, full-up, totally committed observing program to be accomplished.

Mr. VOLKMER. We'd just limit what you can do? What you——

Dr. HINNERS. It would change the nature of the observations in that given time period, correct.

Mr. VOLKMER. Yes; and, but there is a strong possibility, I think at least from what I see now is that there is a strong possibility that not every instrument would be working before we'd have replacement instruments prepared to go up. In other words, with the number of instruments that are there the number of replacements contemplated could be before we could have our second one or third one, or even the fourth one, actually you could be talking 9 or 10 years, could you not?

Mr. KELLER. Certainly before you have three or four instruments it will be at least 9 or 10 years.

Mr. VOLKMER. And so we're asking that some of those instruments last that long.

Dr. HINNERS. Which is possible, but I mean it's also possible they could fail.

Mr. KELLER. It is possible. It is quite possible that certainly some will last that long. In fact, it is more likely probable. The question that is less easy to answer is since I can say that one or two will probably last that long with some degree of confidence, I don't know which ones, and it could very well be that when you put a particular complement of instruments together you get more or less science depending on how synergistic they are.

Mr. VOLKMER. I'm going to ask another question in that regard. Let's assume that 3, 4 years from now one of the instruments, whether it is the faint object or the high resolution wide-angle camera, whatever, that one of those would fail. Now, we're going to have to bring it back here to repair it. Who's going to do it? Where's the manpower? What's happened to the people that originally constructed it?

Dr. HINNERS. I'll do it, Sam.

Mr. KELLER. OK. Be my guest.

Mr. VOLKMER. I'd like to know. I mean it's——

Dr. HINNERS. That's a good question.

We are actively working now on the maintenance and refurbishment schedule and planning. We at Goddard work very closely with Marshall. Presently we're taking a look at the whole servicing aspect, particularly in view of our Solar Max experience now, to be sure we have available to us the expertise at Marshall should we need to go up on a repair mission. We're looking with the Institute to keeping expertise in the engineering of the instruments, keeping access to those teams and understanding what we have available in the contractors to do those repairs. But we do not have a final plan and answer for you on that, but it is under active work now to understand how we accomplish that in the long term.

Mr. VOLKMER. I mean it's something we're going to have to face somewhere down the line.

Dr. HINNERS. Absolutely. Absolutely.

Mr. VOLKMER. Unless we think that all the instruments are perfect and are going to last for the life of the telescope.

Dr. HINNERS. We have two interesting data points on that, Mr. Chairman. The Copernicus Observatory went for 8 years, and actu-

ally there was the instrument which went after the 8 years. The spacecraft is still working quite well.

On the other side, we have the International Ultraviolet Explorer which is now in its seventh year and the instrument is working just fine on it. The spacecraft is still working. We're getting a little antsy about it, but some 6 or 7 years does not seem unreasonable on both the spacecraft and the instruments.

Mr. VOLKMER. All right. Now, to—are we still staying with the proposal to return the space telescope for ground refurbishment every 5 years?

Mr. KELLER. No, sir. We—the specific answer to your question is no. The details are still being worked. The reason I say the specific answer is no is that it would, I am sure, be a longer period of time than 5 years if we were to bring the telescope back.

Now, you will recall that in the rebaselining activity we have added a number of orbital replacement units that were not there before. For example, the main computer on a spacecraft is not replaceable. The solar panels are replaceable. The momentum wheels are replaceable; replaceable in the sense that they are very easy to get at and with a small number of manipulations they can be removed. That would, we believe, increase the period of time before which we would have to come back.

Further, we have not been able to totally evaluate this yet. The experience that we achieved on the solar max repair mission would indicate to us that we have a capability to do much more than we had planned. A number of the activities that were conducted successfully on that mission were with systems that we would not describe as orbital replacement units. So we can do more than we thought.

The third thing that enters into this is, as a part of the Space Station Program, ultimately we will achieve the on orbit capability. Perhaps more importantly, in conjunction with that program we will develop more advanced astronaut suits and things of this nature that will, even though operating from the shuttle, give us more flexibility and more capability to do things that have not been planned.

We are in the process and have underway a study now to review the space telescope and try to identify, based on some assumptions as to what a space station capability might reasonably be, are there any particular units that could not be replaced on orbit, or repaired. Now, we're very fortunate in that we have a large system here.

The access doors, for example, to the equipment section are like 3 feet by 5 feet. The boxes aren't full of equipment jammed on top of each other. In fact, we have the very team that did the solar max repair mission looking at it for us. And we would hope within a reasonable period of time to come up with an assessment of the validity of what I would characterize as at least an objective now, which is to develop a plan to not bring the telescope back, to not expose it to the hazards of a relanding activity, and not expose to the potential contamination of ground operations. We don't have an answer right now, but we will certainly keep the committee informed as these activities progress.

Mr. VOLKMER. Before I recess again—we've got another vote on—I'd like to first find out if any of you have any timeframe which you have to leave let's say in the next 10 or 15 minutes. If you do, it's all right, and we'll submit the additional questions in writing. Otherwise, I'd like—I do have some additional questions I'd like to come back and finish up if you can stay. Just for——

Dr. EDELSON. I'd like to be excused, Mr. Chairman, if I may.

Mr. VOLKMER. That's quite all right.

Dr. EDELSON. Thank you.

Mr. VOLKMER. I'll be back in a few minutes.

[Recess.]

Mr. VOLKMER. To get back to the maintenance, refurbishment, and operations, I notice that the provisions for these in 1983 and 1984 have increased. Do you see these continuing to increase?

Anybody want to address that? If not, we'll——

Mr. KELLER. Did you say maintenance, refurbishment, and operations?

Mr. VOLKMER. And operations, right.

Mr. KELLER. I think the maintenance and refurbishment has really been going down because we've been holding expenditures back.

Mr. VOLKMER. Right.

Mr. KELLER. The operations line has shown some increase. In part, we've had some development overruns and they did occur in the past with the ground system. In going through and restructuring the entire program, we found elements that had been left out. I think the numbers that we have right now may be subject to a 1-year perturbation. I'm really just speculating myself on that from what I've heard.

We are working very diligently right now to contain these costs and to maintain them at a level of effort with inflationary effects accounted for only. We have not completed our discussions with the Institute, the science community, and the other people that will utilize the telescope. I think the entire system is extremely sensitive to the implications of a growth in this budget. Because it is clear that the entire Space Sciences Program is contesting for some finite sum of money, and every dollar that we spend on this program, or any other program, reduces our ability to conduct as broad a gauge program as we would like.

So we are working to contain those numbers. I think we are—we have a much better handle on them now than we did a year ago. I would not tell you that there will not be any growth in the future, but I don't think it will be a dramatic increase.

Mr. VOLKMER. I recognize the gentleman from California at the present time. I still have a couple more questions, but I'll recognize him for some now.

Mr. LOWERY. Thank you, Mr. Chairman.

Dr. Hinners, I have some concerns with the research program, and I've got three major questions. How will the actual proposals for observation time on the space telescope be funded?

Dr. HINNERS. The Space Telescope Science Institute will receive proposals, conduct a peer review of those proposals, and then allocate funding. The funding will come, of course, from NASA to the Telescope Institute to fund the guest observers.

Mr. LOWERY. So out of the $50 million?

Dr. HINNERS. Right.

Mr. LOWERY. Is it the intention to lump them into a budget line item? And what happens if the Institute or the Goddard cost actually increase? Does science get less? How does that work?

Dr. HINNERS. That refers——

Mr. LOWERY. They get whatever is left over?

Dr. HINNERS. That refers back to what Mr. Keller was saying. That what our objective is, is to contain, restrain what we call the operations cost, which then means that for a given budget more dollars go into supporting the observations or the data analysis. And that is the costs——

Mr. LOWERY. You're going to restrain your overhead costs, then?

Dr. HINNERS. That's correct.

Mr. LOWERY. What's the impact of increasing the number of visiting scientists or general observers from 200 to 600?

Dr. HINNERS. Twofold. No. 1, we're not——

Mr. LOWERY. How did you originally arrive at that 200 figure?

Dr. HINNERS. The 200 was based on experience with ongoing observatories; for instance, the Copernicus, the discussed investigative program, the International Ultraviolet Explorer. Then looking at the instruments on the telescope, roughly figuring how much time it would take for observations. So it was a rough estimate.

We think the 600 number, which we've heard and which people have talked about, is probably on the high side. Three hundred, 400, may indeed be a number which we'll get. We expect a lot of proposals. We'll just have to work out how many guest observers actually get funded. The limits on how many you deal with and how you deal with them is a function both of the facility capability and the amount of time a guest observer spends, say, at the Institute. This was configured initially, I believe, by the Institute figuring 2 weeks that each guest observer would spend at the Institute. Our experience, based on the IUE, and looking at how Kitt Peak operates, is that that's probably wrong by a factor of 2, and that more—and the 5 day to 7 day time is reasonable.

So we could accommodate in terms of numbers we think the 400 within the current space allocations. Now, each time you add a new observer you do add on the funding necessary to fund the data analysis. So I suspect that the constraint is going to be more one of funding availability generally.

Mr. LOWERY. Just for argument sake, if we went from 200 to 600, what cost increases would that actually represent?

Dr. HINNERS. I don't have——

Mr. LOWERY. An estimate in terms of dollars?

Dr. HINNERS. I don't have a good estimate, Mr. Chairman. We could attempt to get you one and answer that for the record.

[The material referred to follows:]

The Space Telescope post-launch operations funding level is currently estimated at approximately $50–$60 million per year (FY 1985 dollars). We estimate that the Research Support (Science Investigations) will require 30–50 percent of the post-launch operations funding or $15–$20 million based on support of approximately 200 observation programs per year. Based on this information, our best estimate of the funding required to support 600 observation programs per year would be an increase on the order of $25 million annually or a little more than double the baseline cost. In addition, there would be about $6 million of non-recurring cost associated with

support requirements such as purchase of equipment, etc., for the additional observation programs.

Mr. LOWERY. OK. If you could, that would be helpful. But there's no intention of expanding the pie. We have a limited amount of resources available regardless of how many projects and observers we're going to fund.

Dr. HINNERS. That's right. There is not a definite number established yet. We have estimates, but we need to work those details. And again it's a function of what the competition is with our funding.

Mr. VOLKMER. Will the gentleman yield on that just a moment——

Mr. LOWERY. Be glad to, Mr. Chairman.

Mr. VOLKMER [continuing]. So I can have a clarification in my own mind. Because we have the Science Institute over here and we have Goddard here, and when it comes down to which investigations are to be made, what areas specifically are to be investigated at this time or throughout a time period, isn't that going to be decided basically by the Director with a recommendation, maybe, from the advisory committee to the sciences and not by Goddard?

Dr. HINNERS. That's absolutely correct. The Institute has that responsibility.

Mr. VOLKMER. But then you would have input into basically how much money they're going to be able to spend on the various things. Is that correct, or not?

Dr. HINNERS. No; the budgeting allocation will come from the headquarters program office. Now, Goddard will make recommendations, working with the Institute, as to what the observing program should be, and then we will have to make that in the normal budget process as a recommendation to headquarters. And then that will go through the normal budget cycles to determine what the observing budget can be in any given year.

Mr. VOLKMER. So what would be your function in making those decisions, then, at Goddard?

Dr. HINNERS. Goddard is involved in the operation of the payload operation control center. So ours is mainly looking at the engineering, the health of the observatory, the command handling, taking the science commands from the Institute on down through the control center, out to White Sands, and up. But we do not get directly involved in the process of selecting the observations to be made. That is an Institute function.

Mr. VOLKMER. All right. I yield back.

Mr. LOWERY. Thank you, Mr. Chairman.

Dr. Hinners, in your opening statement you said the cost of the Institute must be restrained so that other NASA missions in space science can be started. What percent of the post-launch budget for the space telescope do you think the Institute will represent?

Dr. HINNERS. Well, the percentage, I couldn't give you a clear answer on that for this reason. One has to look at the Institute functions and the—if we call it the support of the ground system at the Institute, the support of the Institute scientists and their functions as one piece of it, the observers that are supported through that in a sense is passthrough money. In other words, it's not con-

tributing directly to the ongoing operation of the Institute, but that goes on out to the observers.

So I think our objective, again, is to keep the Institute, the pure Institute piece as low as possible but still allowing them, of course, to fulfill their function of supporting the observers, keeping the software systems going, keeping the continuity in the program, and helping those observers do their science data, acquisition, planning their observing programs and helping them with the data analysis.

Mr. LOWERY. Do you have an estimate, though, in terms of the post-launch budget? Round terms?

Dr. HINNERS. Sir, the estimate is about $21 million a year on that at this point.

Mr. LOWERY. So about 40 percent of the total.

Dr. HINNERS. All right.

Mr. LOWERY. $50 million.

Dr. HINNERS. OK.

Mr. LOWERY. A final question. Is there any fat anywhere else in the Space Telescope Program at this point, or is it lean all the way through?

Dr. HINNERS. It is lean all the way through.

Mr. LOWERY. So is it—should we on the Space Subcommittee expect to see some budget growth in this program? Or do you think it's lean but realistic?

Dr. HINNERS. I believe so.

Mr. KELLER. I think, if I could respond to that.

Mr. LOWERY. Please.

Mr. KELLER. There are three budget line items. One is the space telescope development line. That is the one that we have committed to complete the development for $1.175 billion. We intend to do that, and we foresee——

Mr. LOWERY. For that amount of money?

Mr. KELLER. Yes, sir. We will deliver—everything in that line item we will deliver it for those dollars, and we see no reason why that will not happen.

Now, the other two lines, operations and maintenance repair, go on forever, as long as the telescope lasts. So what you will notice each year is that number gets bigger, because each year we add another year into our budgeting cycle. So, you know, you can say, well, it costs a billion dollars to run a telescope, or $10 billion, it depends on how long it lasts. That kind of cost growth will continue.

Now, we anticipate in the operations area a fairly level activity which will fund the cost of the control centers and the ground system at Goddard and fund the cost of the operations at the Space Telescope Science Institute. That money comes out of what we call space telescope operations money.

I'm responding to a question you alluded to earlier: Are these the same kinds of money, or how are they funded? The research activities, which is about $10 million to $12 million a year, the research activities by the scientists, which is the so-called pastoral money which is administered for NASA by the Space Telescope Science Institute comes out of the research and analysis account. So that's a different account and will be handled and compete with other research activities.

So—and the third area is maintenance and repair. And that again, as I say, we have a fairly periodic probable revisit program because of failures, and as we discussed somewhat earlier, we are reassessing the need to bring the telescope back to the ground for maintenance. And if we're able to maintain this instrument on orbit, we think there'll be a significant reduction in the total cost involved.

Mr. LOWERY. Thank you very much.

Thank you, Mr. Chairman. I, regrettably, have two other hearings going simultaneously, but I appreciate the opportunity to get those questions in. Thank you.

Mr. VOLKMER. I have a few more, and then I'm going to have some questions in writing that I'll submit to you and request that you get them back to us within the next few weeks.

But before I conclude and we go to our final witness, you all have discussed, Dr. Lucas and Mr. Keller, the possibility in the future of using the space station in refurbishment. Is that correct?

Mr. KELLER. Yes, sir.

Mr. VOLKMER. Now, what we're looking at I think up here from this side is that in all probability that space station won't be operational at least until 1992, and we've got 6 years then. And as far as an orbiting maneuverable system on this up there, we're looking at even past that.

Now, how are we going to refurbish if refurbishment is desired prior to that time?

Mr. KELLER. I think we will be gradually acquiring, over this period of time, an increased capability which we will during the early years exercise by utilizing the shuttle and the things that can be done from the shuttle. This, in particular, is where we would expect the experience from Solar Max mission, for example, to come to bear. This is where the additional ORU's, orbital replacement units, that we have built into the system will come to bear.

We think that one of the earlier benefits to the program from the space station will be the development of the improved astronaut suits, which is a part of the Space Station Program that's now being developed. To the extent that we can provide for additional maneuverability and flexibility by the astronaut so that while he is suited up he more nearly approximates normal working conditions, then our ability to do more complex repair jobs is increased.

As we've said earlier, we had a nominal 5-year period of time. We can't get very precise, but we believe that the additional orbital replacement units we've put into the space telescope will increase the time period when you'd bring it back the first time. Hopefully, the failures we have will be soft failures. We would assume that we would have a gradual degradation, and we design the spacecraft so that that will happen in function and ability as a spacecraft should age.

We don't believe that there will be a particular time, day and hour when we—you know, now is when it becomes inoperative, but rather as the lifetime continues we will lose first one and then another of the flexible capabilities we have. We hope that our analysis which we will conduct over the next several months will show that it is very reasonable to expect the increasing capabilities to

come on line before we're faced with the need for some dramatic activity.

Mr. VOLKMER. Dr. Hinners, one other area that I'd like to discuss is in the SOGS and in the problems that have developed since we do have the Space Institutes. As I understand it, there are some problems in regard to designing the software to permit the telescope to guide in and hold on the planets that are moving, et cetera; is that correct?

Dr. HINNERS. We have not fully implemented the software capability to do all the, what's called the moving target——

Mr. VOLKMER. Right.

Dr. HINNERS [continuing]. Tracking and acquisition. And as I mentioned before, part of that capability will not be in initial software available at launch, but we will implement that as part of the evolution of the SOGS. So we expect that that will be put in, in a year, 2 years after launch.

Mr. VOLKMER. But you do not see that as being an insurmountable task?

Dr. HINNERS. Oh, no, absolutely not.

Mr. VOLKMER. All right.

Dr. HINNERS. It's a matter of timing and the budgeting.

Mr. VOLKMER. All right.

Dr. HINNERS. And that is for a very specialized target. That is for such things as following, say, a moon of Jupiter as it's going around another moving target. For the normal astronomy observations it is not a problem. Cometary observations would be another place where it's required.

Mr. VOLKMER. Again, in regard to the SOGS operation and the total budgetary constraint, that has increased also; is that correct?

Dr. HINNERS. That's correct.

Mr. VOLKMER. Do you see a continuation of that increase——

Dr. HINNERS. No; I think the——

Mr. VOLKMER [continuing]. The same growth factors we've seen?

Dr. HINNERS. No; we have the initial SOGS development now well scoped, the schedule understood. So I view the other change as part of what we call a SOGS maintenance and evolution. As we learn more about its use in the early operations of the telescope, and we'll find new things to do with the telescope which will then require updating and upgrading of the software.

Mr. VOLKMER. In that regard, Mr. Keller, I'd appreciate it if you all could furnish to the committee a, if you can, a basic breakdown of what you project for the future for such things as operation of SOGS and money to go—that part of the total budget that would go to the Science Institute for investigations. This is after 1986.

Mr. KELLER. Yes, sir.

Mr. VOLKMER. We're talking about 1987 on through maybe 1990, 3 or 4 years. What it looks like, and then how much is going to be in there for maintenance, refurbishment, spare instruments, what have you—I'd like to have that if I could.

Mr. KELLER. Yes, Mr.——

Mr. VOLKMER. Give us some idea of what we're talking about as far as once we get it operational what it's going to cost us.

Mr. KELLER. We'll be pleased to provide that information recognizing that some of that we're still working, particularly in the maintenance and repair area.

Mr. VOLKMER. All right.

[The information follows:]

The Space Telescope post-launch operations funding level is currently estimated at approximately $50 to $60 million per year (FY 1985 dollars). Of this projected Space Telescope Operations funding level, we estimate that the percentages funding for the major elements are approximately as follows:

	Percent
Research support (science investigations)	30–35
Science Institute	25–30
Mission operations (GSFC operations)	10–15
Systems development/upgrading (operations development including SOGS)	15–20

The Space Telescope maintenance and refurbishment (including new instrument development) funding level is currently estimated at approximately $45 to $55 million per year (FY 1985 dollars). It should be noted, however, that we are currently re-examining our maintenance and refurbishment plans to assure that we are undertaking an efficient and cost effective program, and to assure that as much science as possible can be obtained. As stated during the May 24, 1984 hearing, we are pursuing the potential use of the agency generic capabilities for on-orbit maintenance and repair wherever feasible; in addition, we are currently studying the possibility of utilizing the future Space Station for major refurbishment activities to obviate the need for returning the Space Telescope to the Earth for repair and thus allow more potential funding for development of new science instruments. We will keep the Committee informed of our plans and major decisions regarding the future ST maintenance and refurbishment activities.

Mr. KELLER. If I could, sir, state for the record, I've been passed a note, and my statement that the passthrough money came out of the research and analysis account was incorrect. It is, in fact, in the operations line. It is not my intent to announce a change in our budget structure this morning.

Mr. VOLKMER. All right. Now, earlier on it appeared to me that, Mr. Keller, that you lead me to believe that if we come up to launch time and some of the instruments just aren't up to par the way you wanted them to be but that they—overall the telescope would be able to function and provide data to astronomers that they need, basically, that you would go ahead and launch rather than trying to make it perfect.

Mr. KELLER. Yes, sir; that is a correct statement. I would be very hard pressed to give you the precise hypothetical condition that would cause us to go one way or the other. I think that faced with that possibility we would make a tradeoff involving the science degradation, the cost of the program——

Mr. VOLKMER. Cost of delay.

Mr. KELLER [continuing]. The cost of the delay, the total impact. The one thing I could assure you is that if it is necessary to make a decision like that, and unfortunately we sometimes have to make them, we would certainly involve the scientific community and the users of this instrument in making that decision to the fullest.

Mr. VOLKMER. One last thing, Dr. Lucas. In the event that when the primary mirror is examined, and let's hope it doesn't occur and I don't think it will, if there's any molecular contamination we'd like to know about it right away.

Dr. LUCAS. Yes, sir; we'll certainly provide that information to you.

Mr. VOLKMER. Let's hope there's not.

That will conclude this testimony. I do have a few other questions I have, and we'll submit them to you in writing; they'll be very brief, and appreciate your sending those back for the record.

Thank you very much for being here today, and let's have continued success and maybe in a few years we can have that picture of the telescope up here on the wall, too. OK?

Mr. KELLER. Thank you, Mr. Chairman. We appreciate your interest in the program.

Mr. VOLKMER. And I want to congratulate you on the work that you are doing and, in overcoming the obstacles, that have been done, and I'm sure that we'll all be very happy in a few years. Thank you very much.

Dr. LUCAS. Thank you, Mr. Chairman.

Mr. VOLKMER. Our next witness is Dr. Sandra M. Faber, University of California, the chairperson of the Space Telescope Visiting Committee of the Science Institute.

Dr. Faber, your statement will also be made a part of the permanent record at this point in the record. You may either summarize or review it full, however you so desire. And I do appreciate your attempt to wait this long a time on it, and I apologize for the number of recesses. You may begin. I can't guarantee you that we won't have another vote before you conclude. You may proceed.

STATEMENT OF SANDRA M. FABER, PH.D., UNIVERSITY OF CALIFORNIA, LICK OBSERVATORY, SANTA CRUZ, CA, AND CHAIRPERSON OF THE SPACE TELESCOPE VISITING COMMITTEE OF THE SCIENCE INSTITUTE

Dr. FABER. Thank you very much.

You have a preliminary written statement from me. However, I thought it wise to reserve the bulk of my preparation until the annual meeting of our visiting committee could take place, which did take place on Monday through Wednesday of this week. So, in fact, I would really like to say rather little about my written testimony, which concerns itself mostly with what the visiting committee is and how it operates, and concentrate instead this morning on really the findings of our recent meeting, if that's satisfactory with you, sir.

Mr. VOLKMER. Yes; that would be fine.

Dr. FABER. All right. So I do have a handwritten statement here, but my oral testimony, then, will be what I wish to contribute to the record.

Mr. VOLKMER. That's quite all right.

Dr. FABER. I would like to report to you today on the visiting committee's overall impression of the present status of the Science Institute and the role it is playing within the space telescope project. Our overall impression of the Institute is very positive. The staff of the Institute is dedicated, dynamic, and competent. They work long hours and the product they produce is good.

The visiting committee further believes that the tasks that the Institute is performing now are highly relevant to the success of the space telescope project. Let me just summarize the nature of some of these tasks briefly.

Among other things the Institute has major responsibility for the development of software to analyze the data, the scientific data, once they are transmitted back to Earth. The Institute also plays an important role in scheduling the telescope and operating it in orbit. Under the direction of NASA, the Institute staff is currently reviewing the software and procedures needed to carry out these functions and is negotiating some improvements that need to be made, most notably to the Science Operations Ground System [SOGS].

A further major portion of the Institute effort is devoted to developing specific observing stategies, more proper sequencing of observations, for example, and to planning the calibration of the onboard scientific instruments before and during flight.

A final task of the Institute, newly gotten underway during the last year, involve several aspects of service to the astronomical community. This service was the single most important reason for the creation of the telescope, to provide the necessary information to help them prepare their observing proposals, read these proposals, arrange for a fair and equitable procedure to allocate the available telescope time, select and administer general observer support grants, and assist astronomers who have received time in reducing and analyzing their data.

Preparation and planning for these activities is now well underway. One of the major questions being asked is just how many proposals per telescope time the Institute will receive and how many of these proposals should be accepted. A major concern here is the anticipated high oversubscription factor. As I shall discuss subsequently, this oversubscription of time is expected to be very large, and it is understandably tempting under such circumstances to divide the time into many small pieces to satisfy as many users as possible.

However, it is the prevailing opinion in the astronomical community that an effective scientific program cannot be mounted with such a strategy since major programs needing large allotments of time would be precluded. In view of these conflicting pressures it is clear that fair and wise allocation of telescope time will be a major responsibility of the Science Institute and must be planned for carefully in advance.

To plan sensibly, the Institute thought it wise to obtain an accurate advance assessment of how big user demand is likely to be and what kind of mix of proposals is likely to be received. To better assess this demand, the Institute mailed a detailed questionnaire to 7,500 astronomers all over the world, 3,000 astronomers responded, and of these, some 1,600 indicated their intent to submit proposals at launch. A more reasonable steady-state load on the Institute is probably 1,500 proposals of all types coming in annually well after launch.

In a parallel planning study a distinguished advisory committee concluded that an optimum scientific program for the telescope could accommodate approximately 300 proposals in total. This large oversubscription factor of 3 or 5 to 1, depending on exactly how one calculates it, emphasizes the need for proper screening procedures that I noted above.

I would also like to stress the following point. The high percentage of responses to the Institute questionnaire and the large number of prospective users of space telescope that it revealed demonstrates more clearly than any previous survey the extraordinary enthusiasm for the space telescope project that exists among astronomers and the widespread consensus in the community that space telescope will revolutionize ultraviolet and optical astronomy as we now know it.

A major factor in establishing the Science Institute and outlining its function and composition was the Hornig report prepared some years ago by the National Academy of Sciences. The visiting committee spent some of its time in considering whether the Science Institute, in practice, is developing along the lines that are consistent with the precepts of this report. Our committee concludes that it is, and that the Institute is so far generally on the right track. More specifically, we believe that it has proved extremely useful so far in the space telescope project to have a group of scientists in place well before the telescope is launched to advise NASA on scientific matters, review the interactions between various phases of the project, and plan for the data handling analysis after launch. The project is an extremely complex one, and it is important to have a group of astronomers with a global view, such as the Institute has been able to take.

The planning activities for educating and servicing the astronomical community are also essential. In total, then, we feel that the present activities of the Science Institute are very much in the spirit of the Hornig report and are consistent with maximizing the scientific return from the ST mission.

While acknowledging the above, the visiting committee also recognizes that the present size of the Institute is significantly larger than originally planned. To put this growth in perspective, one notes that the entire ST project as a whole has turned out to be somewhat larger and more complex than originally envisioned. Some of these extra tasks in the prelaunch phase have devolved upon the Institute. The postlaunch operations have likewise turned out to be more complex than anticipated. For these reasons, the original Hornig staffing levels probably should not be taken too literally.

At the same time we also recognize that costs of the Institute should not be allowed to grow unduly as the total budget for space astronomy in the United States is limited and room must be found in it to pursue other deserving projects beyond space telescope.

Balancing these two needs, it is the feeling of the visiting committee that the present level of effort at the Institute is close to the proper one.

I would finally like to mention an aspect of the ST project that may eventually have as great an impact on astronomy as the initial data themselves. I'm referring here to the data archive system being planned at the Science Institute. The precise medium for storing and disseminating data in the archives is still under study, but the plan now is to store all telescope exposures, both spectroscopic exposures and camera pictures, in a large library. After a proprietary period has passed, roughly 1 year, all data enter the public domain where they can be used by any inter-

ested scientist. This policy has been followed by previous spacecraft experiments, notably the International Ultraviolet Explorer, where it has provided—where it has proved quite successful.

In view of the extraordinary demand for space telescope data, we anticipate that after a few years archival researchers may be as numerous as actual observers on the telescope. The Institute is cognizant of the fact that the archives are an ideal way to provide access to space telescope for those astronomers who cannot themselves be allotted time due to high demand, and it is studying ways to make archival access convenient and widely available.

Because the data is so rich it is anticipated that a great many astronomical questions can be studied with the archives beyond those envisioned by the original proposers. In this way the useful lifetime of the data may extend many years beyond the operation of the observatory in orbit.

That's the conclusion of my prepared remarks. I'd like to address the committee just briefly now as an astronomer from the astronomical community who anticipates using the telescope herself, in my own scientific research. To understand my remarks one must take note of the fact that there are many different kinds of astronomy, centered basically in different wavelength ranges: ultraviolet, x-ray, optical, radio, and so on. And in most of these fields there have been spectacular technical advances over the past few decades: New radio telescopes with spectacular angular resolution, spacecraft experiments in the x ray, and so on. And through all of this the optical ground-based observers have looked on with vicarious pleasure but some envy at their colleagues and wondered what it might some day be like in order to participate in one of these stupendous explosions of knowledge.

As an optical observer hoping to take advantage of the telescope, I feel that it will be a truly enormous step forward in the field of optical ultraviolet astronomy, and I'd like to express my great gratitude to this committee, the Federal Government, and all of those whose vision participated and made this project a success.

Thank you very much.

[The prepared statement of Dr. Faber follows:]

Prepared Statement on the Space Telescope Science Institute

for the

House Subcommittee on Space Science and Applications

by

S. M. Faber
Professor, Lick Observatory, University of California, Santa Cruz
and
Chairman, Space Telescope Science Institute Visiting Committee

May 24, 1984

As of this writing, the Space Telescope Science Institute Visiting Committee (IVC) has not yet held its annual meeting. This event is scheduled for May 21-23, 1984, directly prior to the date of the present hearing. Pending the results of the committee's review, this written statement presents only a brief description of the IVC -- its charge, membership, and method of operation -- and a short summary of the major items to be discussed at the upcoming meeting.

The IVC is an oversight committee charged to provide peer review of the STScI by the astronomical community. It meets once yearly at the Institute and is presently composed of six professional astronomers and space physicists, plus one member from the business community. The present roster of members and their affiliations is included as an appendix. The committee came into existence recently in the spring of 1983 and has had only one year of operation. I have served as chairman of the committee since its inception.

Prior to the annual meeting, the chairman of the IVC is responsible for drawing up a draft agenda. This is done in consultation with the STScI director, since his cooperation is necessary in scheduling interviews with STScI personnel. My own method in preparing the agenda involves numerous telephone calls -- to STScI staff members, NASA and AURA personnel, plus astronomers in the outside community. As a result of these contacts, most of the major issues are fairly

clear before the meeting begins, and the draft agenda focusses on items that I feel are most pressing. I also arrange for the mailing of all relevant NASA and STScI reports to other IVC members in advance of the meeing.

In the first portion of the review, the IVC interviews key individuals and gathers pertinent data. The Director and his staff present a brief summary on the status and activities of STScI. The Director also has an opportunity to present a list of main issues and concerns. To obtain an inside view of the organization, the committee privately interviews several staff members from different branches of STScI. The IVC also inspects various areas of the premises in person. A meeting is also scheduled with several representatives from NASA Headquarters and Goddard Space Flight Center, to solicit NASA's views on how well the Institute is doing.

In the second portion of the meeting, the IVC formulates its major conclusions and discusses them in draft outline with the STScI director and the president of AURA. In the final stages, draft sections of the report are written for editing and merging into a final version by the chairman. After approval by all members, the report is submitted to AURA. Along with responses by the STScI director and by AURA, it is finally forwarded to NASA, accompanied by a formal presentation by the IVC chairman. (Last year's presentation did not occur, owing to illness on my part.)

Based on its first meeting last year, the IVC concluded that STScI is potentially an extremely valuable organization in maximizing the scientific output of Space Telescope and in helping the astronomical community gain efficient access to ST. Overall, the IVC feels that STScI is developing in a manner consistent with the guidelines of the Hornig Report. Its report also gave the STScI staff high marks for competence and diligence and noted that, for a rather young organization, a lot seemed to have been accomplished in a short time.

Two major issues have surfaced for this year's meeting. The first is the fact that the scientific staff is still not able to spend its nominally allotted portion of time on scientific research, owing to very heavy functional responsibilities to the ST project. This factor is adversely affecting staff morale and makes it hard for STSci to hire good people.

A second serious issue is the size and scope of the Institute in the near and far term, and the amount of space needed to house all its functions. The budget of the Institute has increased somewhat over originally projected levels, and there is concern in some circles that it may be growing too large. The IVC will be focussing particularly on the desirable steady-state size of the Institute well after launch. To highlight particular areas of disagreement between STScI, AURA, and NASA on this issue, the IVC has asked NASA Headquarters, NASA-Goddard, and STScI management to respond to a questionnaire on long-term staffing levels and space needs. All three groups are at the moment working hard to complete this questionnaire before the meeting.

I intend to prepare an oral summary of the IVC meeting for presentation before your Subcommittee on May 24, 1984, in which these and other issues will be discussed in greater detail.

Members of the Space Telescope Science
Institute Visiting Committee

May 1984

Dr. Roger Angel
Steward Observatory
University of Arizona

Dr. Sandra Faber, Chairman
Lick Observatory
University of California, Santa Cruz

Dr. Herbert Friedman
Formerly of Naval Research Laboratory

Mr. William Golden
New York, NY

Dr. David Heeschen
National Radio Astronomy Observatory

Dr. Malcolm Longair, Director
Royal Observatory, Edinburgh

Dr. Peter Lyman, Associate Director
Jet Propulsion Laboratory

Sandra M. Faber

Curriculum Vitae

Date of Birth:	December 28, 1944
Place of Birth:	Boston, Massachusetts
Married:	June 9, 1967, to Andrew L. Faber
Children:	Two girls, Robin L. and Holly I. Faber
Education:	B.A., 1966, Swarthmore College, with High Honors, Major in physics, Minors in mathematics and astronomy PH.D., 1972, Harvard University, in astronomy

Employment:

1966	Summer Research Assistant, Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D.C.
1972-1977	Assistant Professor/Assistant Astronomer, Lick Observatory, University of California, Santa Cruz
1972-1979	Associate Professor/Associate Astronomer, Lick Observatory, University of California, Santa Cruz
1979-present	Professor/Astronomer, Lick Observatory, University of California, Santa Cruz

Honors and Awards:

1964	Phi Beta Kappa Prize, Swarthmore College
1966	Sigma Xi
1966	Phi Beta Kappa
1966-1971	National Science Foundation Graduate Fellow
1966-1971	Woodrow Wilson Graduate Fellow (Honorary)
1971	Carnegie Institution Pre-Doctoral Fellow
1978	Bart J. Bok Prize, Harvard University
1977-1981	Alfred P. Sloan Foundation Fellow

Professional Associations
and Positions Held:

1975-	International Astronomical Union
1967-	American Astronomical Society:
1978-1980	Chair, External Awards Committee
1979-1982	Member, U.S. National Committee for the I.A.U.
1981-1983	Member, Warner-Pierce Prize Committee
1982	Chair, Warner-Pierce Prize Committee
1982-	Member, Light, Air, and Radio Pollution Committee
1982-1983	Chair, Tinsley Award Fund-Raising Committee
1982-1984	Councilor

Other Memberships
and Appointments:

1975-1976	Cerro Tololo Interamerican Observatory, Time Assignment Committee
1978	Visiting Lecturer, Princeton University
1979-1981	Kitt Peak National Observatory, Time Assignment Committee
1979-1981	National Science Foundation, Astronomy Advisory Committee
1979-1982	National Academy of Sciences Astronomy Survey Panel (Field Committee); chair of the Extragalactic Working Group
1982-1986	Editorial Board, Annual Reviews of Astronomy and Astrophysics
1982	Phillips Visitor, Haverford College
1982-	Associate Editor, Astrophysical Journal Letters
1982-	University of California Ten Meter Telescope Astronomy Advisory Committee
1983	Visiting Lecturer, Institute of Astronomy, University of Hawaii
1983-	Chair, Space Telescope Science Institute Visiting Committee
1983-	National New Technology Telescope Scientific Advisory Committee

Miscellaneous:

1977-	Lick Observatory liason to local governments on light pollution
1977-1979	Member, Princeton Wide-Field Camera Team for Space Telescope

Mr. VOLKMER. Thank you, Dr. Faber. I do have several questions. We had testimony, of course, just 2 days ago, last Tuesday, from the other scientists with the Advisory Committee and the Science Institute, and I just wondered—we had some problems in the growth in the numbers that were originally envisioned both in operations and possibly in investigators, envisioned back when the Hornig report was made in 1976. And as I understand it, your committee has been operating since that time, since 1976?

Dr. FABER. No, our visiting committee has been in operation only 1 year. This is our second visit to the Institute.

Mr. VOLKMER. All right. You have testified that you're satisfied with the Institute personnel and director, et cetera, that we have presently onboard. If there are budget constraints, it's going to be necessary, of course, to have people to operate the telescope and give the commands, et cetera, that are going to be needed. If the numbers of these are to such an extent that it may be necessary to reduce the amount that goes to investigators, does that give you any concern?

Dr. FABER. Terrible concern.

Mr. VOLKMER. All right. About how many investigators do you feel that there would be throughout the world? Of course this is not just the United States, but worldwide. How many you think there are potentially?

Dr. FABER. Do you mean number of separate scientific programs scheduled on the telescope per year?

Mr. VOLKMER. That could be scheduled on the telescope, yes.

Dr. FABER. The Institute has, as a result of its survey and the thousands of questionnaires and responses that it's received, been able to look into this question more completely. We heard a detailed presentation, and their feeling now is that the telescope can support in an optimal manner about 300 separate guest observer proposals.

Mr. VOLKMER. That's on an annual basis?

Dr. FABER. On an annual basis. We heard earlier this morning ranges between 200 to 600——

Mr. VOLKMER. Yes.

Dr. FABER [continuing]. And I think their current estimate now is three.

Mr. VOLKMER. And that would depend, of course, upon the type and the length of time that some of those took.

Dr. FABER. Yes; actually most of the proposals, there are a lot of little short proposals——

Mr. VOLKMER. Right.

Dr. FABER [continuing]. Which, however, are very valuable.

Mr. VOLKMER. OK. Have you all looked into the possibility, when you're data being archived and also talk about after an investigator if you have not just a short term but, say, a longer term type of investigation, being able to obtain the data from wherever you are? In other words, you're in California with a software, compatible software, you'd be able to obtain that data, would you not?

Dr. FABER. Yes.

Mr. VOLKMER. Have you all looked into that?

Dr. FABER. Our committee has not yet. I expect on our next visit we'll probably hear a detailed set of proposals for how this might be done.

If I could just elaborate for a moment. I see this remote access as occurring possibly in two levels. And one level I think is absolutely essential, and the other level would be nice but we don't know how expensive it is yet. The first level I think is the capability in which an outside user could dial up the Institute and browse through the catalog the way you might browse through a library card catalog, see what's there and see what you want. That I think would be extraordinarily useful.

It turns out that some kinds of data are very expensive to transmit because they're very lengthy. Other kinds of data, notably the spectroscopic data, would be less expensive and could come in quite easily over the phone lines. So the actual transmission of the data themselves is a more problematic and complicated matter.

Mr. VOLKMER. Do you see any difficulty in cooperation with the, why don't I say the operational staff at Goddard along with the what we call the administrative staff, what have you, at the Science Institute? Do you see any difficulty, or has anything been brought to your attention that——

Dr. FABER. Well, there certainly——

Mr. VOLKMER [continuing]. It would cause any concerns?

Dr. FABER. I don't think there is difficulty to cause concern. I think there is a natural tension between two groups of people which to some extent share different ideals. The ideal of the Institute is, of course, to make its service to the community and the benefit from space telescope, they want to maximize both of those things. Of course that costs money. The motivation of NASA and Goddard, as I understand it, is to deliver an exceptionally—an exceptional product of high quality, but to allow room in the budget to pursue other projects as well.

I think that these two groups are in the process of coming to a meaningful accommodation with one another.

Mr. VOLKMER. Now, are you with—presently with a university?

Dr. FABER. Yes; I am.

Mr. VOLKMER. Southern California?

Dr. FABER. The University of California.

Mr. VOLKMER. Right. As such, is there any concern among the university community as to the possible effect of increased cost in the space telescope in the future and to operations and refurbishment, et cetera, as to the effect that that may have on the other parts of the scientific budget?

Dr. FABER. That concern certainly exists. The nature of it and the degree of it depends a lot on who it is you're talking to. And as you might expect, the areas of greatest concern seem to center in departments which are strongly space oriented and which also depend on NASA for NASA dollars.

I would say that's probably a—that is a serious problem and it's a natural one.

Mr. VOLKMER. Now, do you envision the Science Institute as one which administers a science program, or one which would basically operate a science program? In other words, should the Institute be entitled to go into such things as developing new instruments or

different types of instruments or upgrading the instruments that are there, that type of thing?

Ms. FABER. I think——

Mr. VOLKMER [continuing]. Or do you see it just as one that would be providing access to the telescope for scientific investigators and obtaining the data back for their results?

Ms. FABER. I think the question of instruments is really confusing to me at the present time. And I think there's a great deal of sensitivity, and it's an understandable sensitivity, and it arises in the following way. The Institute is supposed to advise NASA on the refurbishment of the telescope. There is a concern that if the Institute also gets into the business of building instruments it will show some favoritism to its internal investigators and naturally advocate those instruments over others.

The Institute is quite sensitive to this kind of problem. And it is their stated intention at the present time that they will certainly not get into the business of building, and don't want to build instruments on their premises. They don't want to turn into another JPL.

Unfortunately, the question isn't quite that clearcut, however, because it's the opinion of the visiting committee that a considerable degree of technical expertise is necessary on the Institute's staff. Because it almost inevitably happens that spacecraft instruments change over time, they degrade. You need to develop new observing strategies to take into account the change in performance. And this kind of decision necessarily involves some intimate familitarity with the technical details of the instrument. You can't have a person make judgments like that, in your opinion, unless he or she is a technically competent person.

It's hard to attract and keep people like that on your staff unless you give them some outlet for developing whatever personal technical interests they may have. And so the Institute has argued for the presence of a small shop, an electronic shop, a very small machine shop, where staff scientists can undertake very small detector testing programs. And I believe that some of the scientists there want to do that.

That, per se, I think in no way conflicts with the desire not to have the instrument—the Institute build instruments. They're just too far apart. But you can see on this scale of 0 to 10 that there are all levels of activity somewhere in between. And I think what concerns people is some of the gray areas.

I believe that this is a matter that is being actively negotiated between the Institute and Goddard. I think there will be a successful resolution of this dispute.

Mr. VOLKMER. What about the—or do you as a visiting astronomer have any concerns about the in-house personnel, staff personnel having or being allotted a certain amount of time on the—a certain percentage of time on the space telescope?

Dr. FABER. I think that—sir, I think that's a moot question because the Institute—there would be merits on both sides, let me first say that.

Mr. VOLKMER. I mean do you have any concerns on that?

Dr. FABER. I don't think it's going to happen.

Mr. VOLKMER. All right.

Dr. FABER. I don't think it's going to happen because the Institute has sent out its first newsletter to the community which stated a number of ground rules for its operations. And one of those it stated flat out was its staff scientists would not be granted observing time, preferen—guaranteed observing time.

Mr. VOLKMER. We had testimony Tuesday that there is a recommendation that the director be given discretionary time. I believe it's around 15 percent.

Dr. FABER. Well, that's quite different from guaranteed observing time for the staff.

Mr. VOLKMER. Yes, but I think it would be within his discretion to use it for staff or outside investigators.

Dr. FABER. I see.

Mr. VOLKMER. Now, would that give you concern if that occur? Or would that be—in other words, how are we going to hold the staff if they cannot participate?

Dr. FABER. I would think that the staff ought to be eligible to compete and make persuasive proposals for that discretionary time just as anybody else would.

Mr. VOLKMER. All right. That's satisfactory. In other words, you have no objection to them being able to compete with everybody else part time?

Dr. FABER. That's right.

Mr. VOLKMER. Do you have anything else?

All right. The original Hornig report suggested that the Institute have a role in defining maintenance and refurbishment policy from a science standpoint. In your opinion, has any of this occurred as far as the policy decisions so far, that you know of?

Dr. FABER. Not that I know of.

Mr. VOLKMER. All right. Should it occur? Should there be at least some input——

Dr. FABER. Of course.

Mr. VOLKMER [continuing]. In the policy decisions?

Dr. FABER. Yes.

Mr. VOLKMER. As I understand it, at the Institute there's a considerable amount of administrative workload that has to be accomplished. Do you know of any way that this could be alleviated, or do you now of any discussions being—taking place to alleviate that?

Dr. FABER. Our visiting committee asked the Institute and NASA whether or not there were ways to alleviate this workload. We were told that a joint task force, mini task force between the Institute and Goddard had looked into the question and ultimately decided that all of the routine reporting that is currently being done is part of a contract and—either that or somebody really needs it. They didn't feel that any of the routine reports could be reduced. And the Institute seems to agree with this.

Could I elaborate a bit more?

Mr. VOLKMER. Yes.

Dr. FABER. The business office at the Institute does this year feel rather heavily pressed with its total workload. But this year for a variety of reasons they've been—they've had to prepare a number of unusual presentations and reports, and they're hoping that in future years this won't be the case.

Mr. VOLKMER. Kind of startup-type stuff.

I have no further questions. You have any other statement you'd like to make?

Dr. FABER. No, thank you.

Mr. VOLKMER. Thank you very much, Dr. Faber. I appreciate your being here today.

And that will conclude our hearings. The subcommittee will stand adjourned.

[Whereupon, at 12:50 p.m., the subcommittee was adjourned, to reconvene subject to the call of the Chair.]

APPENDIX

Questions and Answers Submitted for the Record

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY CHAIRMAN VOLKMER DURING THE HEARING BEFORE THE HOUSE SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS ON MAY 24, 1984 TO DR. EDELSON.

QUESTION E-1:

Please provide a projection of post-launch costs associated with the Space Telescope by year through the first ten years. Include the following:

- Science Investigation funding
- Science Institute operations
- Contract operations at Goddard
- Operations development such as for archive and SOGS upgrading
- New instrument development
- Instrument repair contingencies and spare parts acquisition
- Attributable costs to the Space Transportation System including instrument transportation, repair missions, and reboost operations
- Refurbishment activities

ANSWER E-1:

The projections of the Space Telescope post launch costs listed in your request, fall into two separate major budget categories, i.e., the first four items are funded within Space Telescope Operations, and the last four items are funded within the Space Telescope Maintenance and Refurbishment program under Physics and Astronomy Mission Operations and Data Analysis.

The Space Telescope post-launch operations funding level is currently estimated at approximately $50 to $60 million per year (FY 1985 dollars). Of this projected Space Telescope Operations funding level, we estimate that the percentages of funding for the major elements are approximately as follow:

	Percentage
- Research Support (Science Investigations)	30-35
- Science Institute	25-30
- Mission Operations (GSFC Operations)	10-15
- Systems Development/upgrading (Operations Development)	15-20

The Space Telescope Maintenance and Refurbishment funding level is currently estimated at approximately $45 to $55 million per year (FY 1985 dollars). It should be noted, however, that we are currently reexamining our maintenance and refurbishment plans to assure that we are undertaking an efficient and cost effective program, and to assure that as much science as possible can be obtained. As stated during the May 24, 1984, hearing, we are pursuing the potential use of the agency generic capabilities for on-orbit maintenance and repair wherever feasible. In addition, we are currently studying the possibility of using the future Space Station for major refurbishment activities to obviate the need for returning the Space Telescope to the Earth for repair. We will keep the Committee informed of our plans and major decisions regarding the future ST maintenance/refurbishment activities.

QUESTION E-2:

According to original plans, the observatory will be refurbished five years after launch.

a. How was this original milestone determined?

b. Please provide a list of operations that were planned to be performed to refurbish the observatory.

c. Which of these would not be feasible to perform on orbit?

d. What are the consequences of delaying the refurbishment milestone?

ANSWER E-2:

a. During Space Telescope Phase A&B studies in the 1970's, best estimates of parts reliability, systems complexity and design redundancy were made. Based on projected failure data, a five year life expectancy was predicted. Subsequently, this requirement was included in all ST contractor end-item specifications as a basis for establishing hardware reliability goals.

b. The basic Space Telescope ground refurbishment requirements originally established were as follows:

1. Replace non-orbital-replaceable hardware
2. Refurbish optics
3. Replace insulation
4. Refurbish thermal control coatings

Further studies defined a KSC-based ground maintenance operation which would consist of the following:

1. Replace degraded/failed components (orbital-replaceable or other).
2. Incorporate any new science instrument(s).
3. Perform systems level testing and re-launch.

c. Based on our current understanding, we believe it will probably not be practical to perform major optical refurbishment on orbit, but many other types of on-orbit refurbishment may be possible. We are putting together a team of people to study the potential refurbishment problems that may be encountered and compare those to the current and planned Space Transportation System capabilities so that we can conduct as many repair/refurbishment activities on-orbit as possible.

d. The original Space Telescope major refurbishment milestone was based on conceptual analysis. However, the need for actual refurbishment will be determined by actual hardware (non-orbital-replaceable) failures. The ground return would be initiated only if no on-orbit work-arounds could be identified, and only if the potential marginal benefits justify the cost.

QUESTION E-3:

In testimony, it was stated that current plans are to use the Space Station as a place for refurbishment.

a. When would the Space Station attain the capability for such an operation?

b. What design criteria does this dictate for the Space Station?

c. Please describe the operation (i.e., How many man-months will it take? Will the observatory be brought to the station? What type of contamination controls are necessary? etc.)

ANSWER E-3:

The use of the Space Station as a service facility for satellites is a concept for which requirements and capabilities are just now being conceptually defined. The Space Station design, of course, is currently being pursued. However, one item which will contribute greatly to on-orbit servicability is a space suit which would provide greater flexibility and maneuverability for the astronauts, and thus greatly enhanced on-orbit refurbishment capability. This in itself could prove to be the major enhancement for Space Telescope servicing. We will continue to work with the Space Station Office within NASA to assure that consideration is given to on-orbit refurbishment during the design phase of the Space Station.

QUESTION E-4:

Please describe the reboost scenario for the following conditions:

a. Average solar cycle with integral Shuttle propulsion system. Active solar cycle with an early maximum and integral shuttle propulsion system.

b. Average solar cycle with augmented Shuttle propulsion system (i.e., with an OMS kit). Active solar cycle with an early maximum and augmented Shuttle propulsion system (i.e., with an OMS kit).

ANSWER E-4:

a. The estimated reboost capability of an integral shuttle propulsion system (standard OMS) for the Space Telescope is 15 nautical miles. Thus, the ST will require a reboost when the altitude decreases from its insertion altitude of about 320 nautical miles to about 305 nautical miles. Under average solar cycle conditions, the reboost would be required approximately seven years after launch.

Under active solar cycle conditions (+2 sigma) with an early maximum, the initial reboost may be necessary as early as late 1988-89.

b. A conservative estimate of the reboost capability of an OMS Payload Bay Kit which was designed to have a higher altitude capability than the standard OMS system, was 75 nautical miles. Under nominal and worst case solar cycle conditions, the initial reboost time would be the same as above.

QUESTION E-5:

What are the present plans for developing an OMS kit capability?

ANSWER E-5:

The original approach to meet anticipated requirements for orbital altitudes above the basic Shuttle orbiter performance was the OMS Payload Bay Kit. This approach was never implemented because only two payloads in the STS mission model had requirements beyond the standard orbiter OMS system: the Solar Maximum Repair Mission and the Space Telescope. An alternative mode, the direct insertion method (longer SSME burn), was selected to satisfy effectively these missions without the significant additional development cost of the OMS Payload Bay Kit. In the case of the Space Telescope, the plan is to launch the spacecraft into a 320 nautical mile orbit, and use the Oribtal Maneuvering Vehicle to reboost the Space Telescope when the orbit decays to about 300 nautical miles. This is currently estimated to be in the late 1988-89 timeframe based on predicted solar activity.

QUESTION E-6:

Please characterize the risk associated with a Shuttle visit to the observatory (for repair, for example) and reboost.

ANSWER E-6:

Some of the risks which are associated with a Shuttle visit to the Space Telescope are:

1. Contamination from proximity Shuttle operations.
2. Malfunctions in the retraction and redeployment of appendages such as solar arrays and antennas.
3. Mechanical damage from inadvertent contact (Remote Manipulator System or EVA-induced).
4. Unforeseen thermal conditions/attitudes.
5. Erroneous EVA techniques.
6. Failure to relatch Space Telescope doors.

All of these risks have been analyzed and the probabilities of occurence are assessed as very low.

The risks associated with reboosting the Space Telescope include the first three risks identified with a Shuttle visit. In addition, there are some potential dynamic loads risks associated with the Space Telescope reboost. However, our current assessment showed the probability of adverse effects, particularly when compared to the shortened lifetime of the Space Telescope, to be acceptable.

QUESTION E-7:

Throughout the development program, associate contractors and NASA field centers have had to fabricate special test equipment which appears to be unique to the Space Telescope.

a. What provisions have you made for the surplusing or disposition of this equipment?

b. How useful would it be for other programs?

c. Could any of this equipment be utilized by the university community?

d. Could this equipment be used for refurbishment activities in the event ground return is necessary?

ANSWER E-7:

NASA's current plans assume that the Space Telescope special test equipment will be placed in storage after launch of the Space Telescope as this equipment may be used for potential required ground refurbishment of the Space Telescope. In addition, this test hardware can most likely be used by future development projects. In addition, some requests for some of the Space Telescope test hardware have been received from the university community.

QUESTION E-8:

There is approximately one month set aside for surface shipment of the observatory from the Lockheed plant to Kennedy Space Center.

a. Is it feasible to ship by air?

b. What would be the difference in costs?

ANSWER E-8:

a. There currently are no aircraft which could accommodate shipment of the Space Telescope by air. However, studies have been conducted jointly by NASA and DOD to determine if a means of air transportation could be developed to transport very large payloads such as Space Telescope. An example of a potential transport mechanism is the development of an external cannister which would be attached to the Shuttle carrier aircraft. However, none of the potential options could be made available for transport of the Space Telescope from the Lockheed plant to the Kennedy Space Center in 1986. The actual cost of the shipment of the Space Telescope by barge versus air would not be significant; the major advantage of the air shipment is that it would decrease the shipping time and possibly simplify the loading/unloading of the Space Telescope.

b. If a courier aircraft with the capability to transport the Space Telescope from the West Coast to KSC were available, the difference in actual shipping costs would not be significant.

RESPONSES TO WRITTEN QUESTIONS SUBMITTED BY CHAIRMAN VOLKMER, MAY 24, 1984, TO DR. WILLIAM R. LUCAS

QUESTION 1:

In your testimony, you described a major upward revision in the specifications for mirror particulate contamination.

a. Please describe how this occurred.

b. To what extent are these specifications independently reviewed by the scientific community?

ANSWER 1:

a. As mentioned in my testimony, visible particulate accumulation does exist on the Space Telescope primary mirror surface, despite rigorous contamination control measures. At the time of my testimony last year, our principal concern was associated with large particles (100 microns and above) and their contribution to scattered light. On that basis, the primary mirror coverage was estimated to be 0.2 percent compared to our on-orbit budget allocation of 1 percent. Subsequent analysis of encircled energy and other scientific requirements revealed that smaller particles (10-100 microns) should be included in our consideration. Inclusion of the smaller particles in the analysis raised the estimate of primary mirror particulate coverage from 0.2 percent to 1.4 percent.

We initiated a review of the particulate contamination control objectives in the fall of 1983, which included a study of the optical performance objectives. This study identified the key requirements which are affected by the particulate contamination. For example, the requirements are that 70 percent of the light in a star image must be focused inside a circle of 0.1 arc second size. Dust particles scatter light out of the circle of focus, thus degrading the image obtained. Given the telescope mirror optical quality and the expected pointing stability, it was calculated that an aerial coverage of the mirror, by dust, of 5 percent can be tolerated without significant light scattering.

b. These specifications have been reviewed by the Space Telescope Project Scientist, the Science Working Group, and scientists participating in the Space Telescope Observatory Performance Assessment Team, and the 5 percent maximum aerial coverage has the endorsement of these scientific advisors.

QUESTION 2:

Over the lifetime of the observatory, how many downstates are likely to occur?

a. How does this affect the science return?

b. How many Space Shuttle visits would this necessitate?

ANSWER 2:

The likelihood of downstates is derived from a mathematical model, which considers the number of parts, systems redundancy, duty cycles, projected failure rates and orbital replacement capability. This math model, which is based on current maintenance and refurbishment planning, indicates that over a projected life of 15 years, the Space Telescope may have about nine downstates.

a. These downstates could result in a nonoperational Space Telescope for approximately 30 percent of a 15-year assumed lifetime, therefore, or a potential of 30 percent loss of science viewing time. Also, some programs requiring an observation continuum time may be affected, depending upon when a downstate occurs. The interruptions would particularly interfere with investigation of invariable and periodic astronomical systems, such as Cepheid stars, that are fundamental indicators of astronomical distance.

b. Based on the above, as many as nine Space Shuttle missions might be required to support the maintenance and refurbishment activities necessary to correct the downstates. Some of these missions could also accomplish required reboosts. We are currently reassessing the maintenance and refurbishment goals because it appears that more extensive on orbit Shuttle repair, or alternately Space Station, could reduce the maintenance and refurbishment costs.

QUESTION 3:

Is it feasible to establish "Level I" requirements for the maintenance and refurbishment program?

ANSWER 3:

Level I requirements for Space Telescope maintenance and refurbishment have always been a part of our planning process; however, we are currently reviewing our planning to see if these requirements can be met in a more efficient and cost-effective mode than previously assumed.

QUESTION 4:

Under what circumstances do you believe a visit to the observatory should be undertaken?

ANSWER 4:

Visits to the Space Telescope while on-orbit may be required to repair or replace a defective system or component that is degrading the operation of the observatory beyond acceptable limits; to remove and replace science instruments that are no longer operable; to update the observatory capability by installing new science instruments; or to retrieve the observatory, if required.

RESPONSES TO THE WRITTEN QUESTIONS TO DR. NOEL. W. HINNERS FROM THE MAY 24, 1984, HEARING.

QUESTION 1:

In our Report accompanying the FY 1983 NASA Authorization, we acknowledged the management difficulties that must be inherent in the Science Institute/Goddard relationship, but we stressed that you must give the Institute a reasonable chance for success.

a. What can be done to fully define the scope of responsibilities of the Institute?

b. Please characterize the present status of administrative vs. research workload for the Institute staff. Is this considered with the Hornig report recommendations?

c. Do you think that the Institute concept would be useful for other major complex observatories such as SIRTF and AXAF?

d. Could the scope of the Institute be enlarged to include other such science operations?

e. How important is it to co-locate the operations, at SOGS for example, with the investigator?

ANSWER 1:

a. The scope of the Space Telescope Science Institute responsibilities has been defined by the 1976 Horning Committee Report and the 1977 NASA response thereto. NASA plans no changes to this definition. The question exists as to the exact magnitude of the staff required to carry out the existing scope or charter. NASA has established its own estimates of an adequate staff size; we have examined some alternatives for achieving a bounding of the Institute-proposed staff growth and we are continuing to negotiate with the Institute/AURA management toward this end. Additionally, NASA has requested the advice of the National Academy of Sciences/Space Science Board; and, a small panel is currently examining this topic. The Board's recommendations are not expected for several months.

b. A distinction should be drawn between "administration of the Space Telescope research program" and "administration of the Space Telescope

Science Institute." In the case of the former, one could picture 100 percent of the Institute staff being involved, since this is the purpose of the Institute and the "administrative" support of the users of the Space Telescope is a primary function. The administration of the Institute as a facility and an organization is the internal responsibility of the Institute's senior and business management staffs. We currently have an independent assessment underway by the National Academy of Public Administration to assess the reasonableness of the size of the Space Telescope Science Institute Business Management Department to carry out the required workload. We are also reviewing potential ways of reducing the required workload without loss of function.

The "research" workload applies to Institute staff scientists (about 30 in number) who have been assured that they will be permitted to conduct their own research projects--in addition to servicing the needs of Space Telescope users. The Institute has a graduated plan that increases from about 20 percent, currently, to 50 percent in the future as a fraction of time each member can spend on his own research. (Incidentally, for Space Telescope time, Institute scientists must compete along with all other potential users.)

c. & d. Since these are related questions, let me address them together. The success of the Institute concept cannot be demonstrated until the Space Telescope has been operational for some time. Since the adoption of the Institute concept (7 years ago), the astronomical community has participated in the very, very successful International Ultraviolet Explorer (IUE) experience and technology has taken dramatic strides toward permitting remote access to and distribution of data. Consequently, I believe that the currently defined scope of the Space Telescope Science Institute is no longer appropriate for planning toward the science programs of the 1990's.

e. For real-time observations (which are estimated to be about 20 percent), it is very important for the observers to participate directly and interact with science operations to support their research. Ground observatories and IUE have operated this way almost exclusively in the past. There is a growing trend both with IUE and ground observatories to observe remotely, with the investigator remaining at his/her home institution and being in contact with the operating site only by telephone or data link. For the majority of observations with Space Telescope (because they will need to be pre-planned and automatically

executed by the onboard computers while Space Telescope is not in communications status with the ground), it is unnecessary for the observer to be on site. However, for non-technical reasons, we expect even these observers to come to the Institute at least once and perhaps several times. In most cases, we anticipate there will be a strong desire on the part of the users to conduct more and more of their data analysis and interpretations at their home facilities.

QUESTION 2:

Please describe the present plans for characterizing the reliability and lifetime of the science instruments.

ANSWER 2:

The five Science Instruments (SI's) and their Control and Data Handling (C&DH) Subsystem will utilize Failure Mode and Effect Analysis (FMEA) and Reliability Predictions to aid in characterizing their reliability and lifetimes. This Space Telescope hardware is also subjected to environmental acceptance tests simulating the launch and orbital environments.

The FMEA examines how the functional elements of the SI and the C&DH might fail during operation and systematically evaluates the impact of the postulated failures on mission objectives. The primary goals of the FMEA are to identify and categorize design weaknesses that could preclude mission success during the design life cycle and to assess the reliability status of various subsystem elements. The SI FMEA report will be used by the Marshall Space Flight Center to provide an overall Space Telescope system level FMEA.

The reliabilty prediction expresses the probability that an SI will perform its orbital science function for its design life.

The FMEA and prediction data will be available by the end of this year.

End item specifications design goal for the SI's on the Space Telescope call for a reliability of 0.85 for the first year of operation. To the extent that our studies have been completed, all SI's except for the highly non-redundant Wide Field/Planetary Camera (WF/PC) have met this design goal. Current prediction of the WF/PC reliability is 0.72.

I believe that the nature of these high-technology SI's is such that the statistical data base used to calculate failure rates is arguably inadequate and/or irrelevant, and that I personally would not draw any conclusions from the resulting calculations. Experience has shown that "reliability" (i.e., longevity) is increased by the use of good quality parts, conservative design approaches, careful construction and quality control techniques, and finally thorough testing and operating time to weed out the "infant mortality" failures associated with electrical components.

The above does apply to each of the five SI's, though I could not extrapolate all those "good things" to a prediction, with any reasonable confidence, that all SI's will function properly for 10 or 20 years. Conversely, I do not believe that all will malfunction within the first five years after launch.

QUESTION 3:

Please describe any plans for establishing a high data rate transmission capability for remote access users to space astronomical observatories.

ANSWER 3:

The accommodation of the remote users during the data analyses phase of observations with Space Telescope is a highly desirable direction. These concepts are not new to us, but they are taking on exciting new dimensions as a result of advancing technology. Both the ongoing development of the Science Data Analysis System and the study effort of the Data Archive and Distribution Services (DADS) for Space Telescope can easily accommodate remote users. The transportability of applications software, as well as data to the remote user sites, is contemplated. The DADS planning assumes low data rate transmission capability, and we have a commitment to share data with our European associates.

QUESTION 4:

When will the SOGS software system be revised to include complex motions and more accessible astrometry data?

ANSWER 4:

Throughout the development of the Space Telescope, these two requirements areas could only be gradually achieved due to their dependence on design of the

pointing control system and elements which support it (fine guidance sensors, control computer software, etc.); these efforts are now nearing completion. An end-to-end engineering data study which includes the Astrometry data functions is two-thirds complete, with implementation tradeoffs and options being actively pursued. The moving target study has recently passed a significant milestone, namely the completion and general agreement on a technical approach for a complete system. Although we will have to reach agreement on how much of the envisioned system is required and by what operational date, we are initiating the next level of definition and initial design at this time. Operational readiness will also depend on the timing/funding tradeoff mentioned above.

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